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PERI-TETHYS PROGRAMME

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Corrélations stratigraphiques de la plate-forme européenne dans le cadre du Programme Péri-Téthys (Introduction générale)

Stratigraphic correlations of European platform in the frame of Peri-Tethys Programme (General Introduction)

Sylvie CRASQUIN-SOLEAU & Patrick DE WEVER

Une synthèse géologique des données disponibles concernant les bassins et les systèmes pétroliers installés sur les plates-formes qui bordent (ou sont incluses dans) les chaînes téthysiennes est actuellement possible car :

1. D'une part de nombreux géologues ont récemment soutenu des thèses de doctorat autour de la Téthys et de nombreux travaux de synthèse ont été effectués par différentes équipes. Le plus souvent, seuls les concepts ont donné lieu à publication alors que les données qui les fondent ne sont pas aisément accessibles ; mais elles sont disponibles en exemplaires à très faible tirage et peuvent être analysées.
2. D'autre part, de nombreuses données industrielles sont légalement abordables (en général dix ans après leur acquisition). Un certain nombre ont été publiées dans un Mémoire du Muséum national d'Histoire naturelle (Peri-Tethys Memoir n° 2, tome 170, 1996).
3. Enfin, l'ouverture des pays qui furent à économie planifiée et accèdent à l'économie de marché est de plus en plus nette ; les informations deviennent accessibles et sont susceptibles d'être compilées avec celles d'autres pays.

Cet état de fait permet l'établissement d'une synthèse de bassins. Cela nécessite :

1. De réunir les équipes qui disposent de l'infor-

It is now possible to synthesize the available data from the basins and their associated petroleum systems which border (or are included in) the Tethyan chains because:

1. Numerous geologists have recently undertaken doctoral thesis in regions around Tethys and numerous synthetic works have been realized by different teams. Often, only the concepts have been published and the data on which these conclusions are based, are not easily available.
2. Many data derived from industry are legally available, in general ten years after their acquisition. Some of these data have been published in a "Mémoire du Muséum national d'Histoire naturelle" (Peri-Tethys Memoir n° 2, tome 170, 1996).
3. The countries which previously had planned economies have begun to be more opened to market forces and those data are becoming more accessible and can now be synthesized with those of other countries.

This situation allows the synthesis of basins in terms of their petroleum systems. This necessitates:

1. The creation of teams which have at their fingertips the data which were not available formerly.
2. To determine a chronological scale and a common vocabulary between the different cultures.

mation (données de base des thèses, données tombées dans le domaine public...).
2. De déterminer une échelle chronologique et un vocabulaire communs aux différentes cultures. Les corrélations stratigraphiques sont actuellement un élément prioritaire à toute tentative de synthèse associant les trois familles de données évoquées ci-dessus.

L'idée du travail est d'examiner le comportement des bassins sédimentaires péri-téthysiens à la lumière des réseaux de contraintes successifs associés à la fin de l'orogenèse varisque, à l'ouverture de la Téthys puis à sa fermeture entre l'Eurasie et l'Afrique-Arabie.

Le Programme Péri-Téthys concerne les régions comprises, au nord en Europe, entre l'Atlantique et l'Oural, au sud, en Afrique-Arabie-Moyen Orient jusqu'à l'océan Indien. Le présent travail concerne uniquement les bassins épi-cratoniques au nord de la Téthys.

La synthèse finale se présentera sous forme d'un atlas de vingt-deux cartes paléogéographiques et de leurs légendes. L'essentiel portera sur les paléoenvironnements et le synchronisme des objets et des étapes physiques.

L'initiative de ce Programme provient d'Europe occidentale : le Programme Téthys (1989-1993) a conduit à une synthèse de l'océan téthysien et de ses marges d'Amérique centrale au travers des chaînes alpines et himalayennes jusqu'aux Philippines, pendant 250 Ma (du Permien terminal au Tortonien). Au noyau de base, où les géologues français étaient largement représentés, se sont joints au cours du Programme de nombreux géologues européens.

Le Programme Péri-Téthys associe à ce noyau des équipes importantes de divers pays d'Europe occidentale (Italie, Pays-Bas, Allemagne, Suisse, Belgique, Royaume Uni...) et des géologues de chacun des pays où sont conduites les études.

Aujourd'hui que les opportunités scientifiques sont facilitées entre chercheurs des pays de l'Est et de l'Ouest, des solutions à de nombreux pro-

At the present time, the problem of stratigraphical correlations is the critical aspect for all attempts which try to synthesize the three types of data mentioned above.

The work purpose is to examine the behaviour of Peri-Tethyan sedimentary basins in the light of the framework provided by the end of the Variscan Orogeny, the opening of the Tethys and finally its closure between Eurasia and the Arabian-African plates.

The region covered by the Peri-Tethys Programme has been limited in the north, in Europe, to the region between the Atlantic Ocean and the Urals and in the south, in Africa Arabia-Middle East as far as Indian Ocean.

The present work is dealing only with the basins to the north of the Tethys.

The final results will be presented in an atlas of twenty-two palaeogeographical maps, with their legend. These maps will include palaeoenvironmental interpretations. Synchronism of objects will be examined as far as possible.

The initiative for this Programme derives from Western Europe: the Tethys Programme (1989-1993) led to a synthesis of the Tethyan Ocean from the margins of Central America via the Alpine chains and the Himalayas to the Philippines during 250 million years (end Permian to Tortonian). During the Programme several European geologists have been added to the initial core which was dominated by the French. The Peri-Tethys Programme has added many teams working in such countries as Italy, the Netherlands, Germany, Switzerland, Belgium... This group has contacted geologists in other countries where there were relevant studies.

Now that scientific exchange is easier between Eastern and Western workers the solutions to many stratigraphic problems may be found through joint projects and enable researchers to compile a more complete fossil record and allow interested workers to develop models that will facilitate more accurate interpretations of geolo-

blèmes stratigraphiques pourront être apportées par le biais des projets communs et permettre aux chercheurs d'établir des inventaires plus complets et par là significatifs, puis d'établir des modèles qui faciliteront des interprétations affinées des bassins géologiques. Notre objectif est de faire des analyses biostratigraphiques des bassins un outil plus performant à la fois pour les chercheurs fondamentaux et appliqués. Des synthèses taxonomiques et stratigraphiques existent aujourd'hui pour des régions téthysiennes, mais souvent aucune corrélation n'est possible avec des aires géographiques orientales sous influence boréale. Cette lacune dans nos connaissances est due à la fois aux domaines paléogéographiques différents (Boréal *vs* Téthysien) et au fait que la plupart des données boréales de l'Est avaient été acquises dans les pays de l'Est où les méthodes et les moyens techniques étaient différents.

gical basins. The goal is to make biostratigraphical basin analyses a more useful tool both for industry and for academics.

Taxonomic and stratigraphic syntheses are published from Tethyan regions but often no correlation is possible with geographical areas which were under Boreal influence. This gap in our knowledge results from different palaeogeographic domains (Boreal *vs* Tethyan) and the fact that much of the Boreal data was acquired in eastern countries where methods and technical means were different.

Moscovian and Artinskian rocks in the frame of the cyclic Permo-Carboniferous deposits of the Carnic Alps and related areas

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Vai G. B. & Venturini C. 1997. — Moscovian and Artinskian rocks in the frame of the cyclic Permo-Carboniferous deposits of the Carnic Alps and related areas, *in* Crasquin-Soleau S. & De Wever P. (eds), Peri-Tethys: stratigraphic correlations, *Geodiversitas* 19 (2) : 173-186.

ABSTRACT
Guidelines and legend for the Moscovian and Artinskian maps to be produced within the Peri-Tethys Programme are presented. An updated review of the most important composite sections exposed in different parts of the Carnic Alps and drilled in the northern Adriatic Sea is presented. The sections spanning a large part of the Mid-Late Carboniferous to terminal Permian time interval are correlated so as to show the major sedimentary cycles and the main regional trends of tectonic *vs* eustatic sea level changes. High frequency cyclicity is also summarized in terms of parasequences, especially for the Gzhelian stage, although the entire Pontebba Supergroup (Moscovian to Artinskian) was known for many decades as a classic cyclic sedimentation area.

KEY WORDS
Palaeogeographic maps,
guidelines,
legend,
low and high frequency cycles,
tectonics,
eustatism,
parasequences,
Gzhelian,
correlation,
Southern Alps,
Adriatic Sea.

RÉSUMÉ
Le schéma directeur et la légende des cartes du Moscovien et de l'Artinskien qui seront réalisées dans le cadre du Programme Péri-Téthys sont proposés. Nous présentons ici une révision des coupes composites les plus importantes des Alpes Carniques et des forages du nord de la Mer Adriatique. Les coupes, qui s'étalent sur une grande partie du Carbonifère moyen-supérieur au Permien terminal, sont corrélées et montrent les principaux cycles sédimentaires ainsi que les modifications tectono-eustatiques majeures. Une cyclicité haute fréquence est également résumée en termes de paraséquences, surtout au Gzhelien, bien que le Super-Groupe de Pontebba (Moscovien-Artinskien) soit connu depuis plusieurs décennies comme une région à sédimentation cyclique.

MOTS CLÉS
cartes paléogéographiques,
directives,
légende,
cycles à faible et haute fréquence,
tectonique,
eustatisme,
paraséquences,
Gzhelien,
corrélation,
Alpes méridionales,
mer Adriatique.

FOREWORD

Before entering the topic of this paper, an introduction is needed to provide the aim, legend, and guidelines according to which the present and the following stratigraphic contributions (Pasini & Vai, Di Stefano & Gullo, Cassinis, Cassinis & Ronchi, Vai, Geluk, all in this volume) have been submitted to the *ad hoc* working group, in view of the compilation of the palaeogeographic maps of the Moscovian and Artinskian within the aims and the scope of the Peri-Tethys Programme (PTP). Further contributions are expected and welcome.

GUIDELINES

The contributions provide original and/or updated stratigraphic rough data on the Moscovian and/or/to Artinskian time slices in the different areas within the scope of the PTP, mainly as spot columnar sections, with the aim to act as validation data points for the following map reconstruction:

1. The Moscovian Map, focusing the Age interval (about 312-305 Ma) and including additional information up to the top of the Carboniferous (about 296 Ma)

2. The Artinskian Map, focusing the Artinskian + Bolorian Age interval (about 280-273 Ma) and including additional information down to the base of the Permian (about 296 Ma).

The Moscovian Stage is used here as roughly represented by the *Aljutovella aljutovica* to *Fusulina cylindrica* fusulinid zones, by the *Idiognathoides marginodosus* to *Idiognathodus obliquus-Neognathodus roundyi* conodont zones, and by the *Paralegoceras* to *Wellerites* ammonoid zones.

The Artinskian + Bolorian Stages are used here as roughly corresponding to the *Chalaroschwagerina solita, Pamirina, Ch. (="Pseudofusulina") vulgaris, Misellina dyhrenfurthi* and *Misellina parvicostata* fusulinid zones, to the *Streptognathodus artinskiensis, Sweetognathus whitei, Neostreptognathodus pequopensis* and *N. leonovae* conodont zones, and are characterized by the new fusulinid genera *Mesoschubertella, Toriyamaia, Praeskinnerella, Darvasella* and by the ammonoid genera *Artinskia, Kargalites, Almites, Cardiella, Paragathiceras, Aristoceratoides, Pseudogastrioceras*. The selected late early Permian time has some advantages: it has a duration almost similar to that of the Moscovian; it is closely equivalent of the Chinese Chihsian and practically overlap with the Yachtash-Bolor faunal step of Leven (1993) comprised between the top of Sakmarian and the base of Kubergandian; it minimizes the imprecision deriving from the poor correlation and definition level of individual stages involved.

It is preferred to receive contributions coordinated in a set of sections by country or group of countries (such as *e.g.*: France, Belgium, UK, Germany, Poland, Hungary, Austria + Tchekia, Bulgaria + Rumania, former Yugoslavia, Turkey, Greece, Italy, Spain, NW Africa, Lybia, Central W Africa, Middle East + Arabia, Iran, Russia + Ukraina, Kazakhstan, a.s.o.). However, submissions provided by independent individuals or research groups are also welcome.

The contributions consist mainly of a set of *spot* columnar sections (stratigraphic columns), possibly correlated on a stratigraphic chart (see f.i. Ziegler 1988), possibly accompanied by location and/or simplified geological maps, and illustrated by a concise explanatory text. The text shall not exceed ten double-spaced typed pages (or five printed pages). Columnar sections, correlation charts (one or more if needed) and location/geological maps must be drawn on A4 sized sheets allowing final print reduction up to 50%. Each individual map drawing must contain a graphic scale.

Columnar sections are to be drawn and correlated on time/space (chronostratigraphic) diagrams. The thickness of the different lithostratigraphic units will appear from separate labelling in a side-column and from the text. The vertical axis of the columnar sections (time) will adopt the geological time scale shown in the next heading.

Each individual columnar section (representing a true spot-like section exposed in the field or drilled by a well, or a composite section whose

TABLE 1. — PTP time scale for the Carboniferous and Permian Periods (ages of the lower boundary in millions years).

Early Triassic	Induan	251 Ma
	Changxingian	255
	Dhzulfian	259
	Midian	264
	Murgabian	269
Late Permian	Kubergandian	273
	Bolorian	275
	Artinskian	280
	Sakmarian	288
Early Permian	Asselian	296
	Gzhelian	301
Late Carboniferous	Kasimovian	305
	Moscovian	312
Middle Carboniferous	Bashkirian	323
	Serpukhovian	328
	Viséan	345

elements are included within the resolution power of a point on a 1:10 000 000 scale map - which is about a circle of 1 km radius) should consist of a main column and a few side-colums. The main column should include lithology, lithostratigraphic units, and depositional environments. The side-columns should include data on thickness, unconformities, rectonic, magmatic and metamorphic events, tectofacies and other additional information (see legend). The location of each section within a resolution power of 1 km of radius should be identified by means of its Latitude and Longitude figures.

If graphically possible, the columns should include the data on both the Moscovian and the Artinskian (plus possibly the intervening interval) on the same sheet (also by using the long side of the A4 sheet).

Drawings should be submitted in both color and black and white (BW) versions, one for the sake of the future map compilation, the other for the immediate purpose of printing the volume. To speed work, it is suggested to label with number (see legend) the different units in the BW version and to fill them by hand colors for the color version.

The structure of the legend mainly conform to the previous one used in Dercourt *et al.* (1993) with some integrations derived from Ziegler (1988), Sassi & Zanferrari (1990) and Vai (1991). It seems particularly useful to include whenever possible in the maps the isopach contours or the margins of the main basins of the late Carboniferous (and Moscovian if available separately) and of the early Permian (plus Artinskian if available separately).

In the present stage, the basic legend type for both the stratigraphic columnar sections and the related geological maps (if available) is reported in Appendixes 2 and 3 respectively.

When additional subdivisions and symbols are needed, they have to be added by the contributors in their own legend sheets, preferably conforming to the use by the authors reported above.

PTP INTERVAL TIME SCALE

The numerical time scale for Carboniferous and Permian chronologic classification down to stage level tentatively adopted for the purposes of the PTP has a simple pragmatic meaning to enable a common frame for communication among different contributors. However, as a matter of fact the present state of chronometric calibration of the conventional stratigraphic scale in the time interval concerned is largely unsatisfactory as appears from the very large error bars (from 3 to 9 Ma) affecting individual stage, series and system boundary ages (Odin 1994). Especially poor is the knowledge about the Dinantian or Mississippian subsystem. The late Carboniferous is mainly dated from continental successions not evenly related to the marine ones. A further limitation derives from the still poor level of formally defined standard chronostratigraphic subdivisions (GSSP) in this time interval. People involved are close to an agreement for the two system and some subsystem boundaries but have not yet paid any attention to the stage boundaries.

In such a condition, our aim was first to have a reliable frame of reasonable duration of stages, regardless of precise boundary ages, and second, to maintain a possible continuity with the time scale used in the previous Tethys Program.

Therefore, the numerical scale adopted here (Table 1) was based mainly on the time scale by

Ross *et al.* (1994), already used in Baud *et al.* (1993), as a preliminary output of the time scale by Menning (1995). Some modifications have been derived from Claoué-Long *et al.* (1995 and pers. comm.), Roberts *et al.* (1995) and from attempts at the best fit with Harland *et al.* (1990) and Odin (1994).

It is hoped that this first group of contributions prompt other interested specialists to provide soon updated informations for those other countries which are relevant for the compilation of an accurate map reconstruction.

LATE CARBONIFEROUS AND EARLY PERMIAN OF THE CARNIC ALPS

The late Moscovian to late Artinskian (*s.l.*) Pontebba Supergroup represents a classic area for late Palaeozoic stratigraphy acting as a bridge connecting the continental Permo-Carboniferous sequence of Western Europe and the marine one of the Russian Platform, the Urals and Middle East to Asia (peri-Tethyan and Tethyan realm). In fact, in the area including at least the Carnic Alps, the Karawanken, the outer Dinarides and the northern Adriatic Sea both facies interfinger conspicously, providing excellent tools for eco-stratigraphic correlations (Kahler & Prey 1963; Selli 1963; Kochansky-Devidé 1965).

Within the frame of the eastern Southern Alps, the Pontebba Supergroup (Venturini *et al.* 1982) represents a superb exposure of a post Hercynian cover (episutural basin) sealing, with sharp angular unconformity, the severely thrusted Hercynian (Palaeocarnic) Chain and its shallow epimetamorphic equivalents of the Comelico basement (Vai 1976; Castellarin & Vai 1981; Vai & Cocozza 1986). The basal unconformity of the Pontebba Supergroup is well exposed over an area some hundreds of square km, although it is intersected by large Mesozoic extensional faults and Alpine thrust faults. Such faults are widely spaced from each other to enable large blocks showing the primary Hercynian basin/cover relationship preserved (Castellarin & Vai 1981). The western correlative of the Pontebba Supergroup is represented by the continental clastics of late Carboniferous (to Permian) age sealing the Southalpine crystalline basement in the Lombardy lake region, Orobic, Giudicarie and Alto Adige areas. Recent research on physical stratigraphy, environmental interpretation and palaeoclimatic evolution has provided the basis for a better understanding also in terms of sequence stratigraphy and sedimentary history (Venturini 1990, 1991; Krainer 1992).

CYCLICITY, SEQUENCES AND TRENDS IN THE PERMO-CARBONIFEROUS PONTEBBA SUPERGROUP (Figs 1-3)

Local autocyclic and tectonic processes as well as over-regional cycles have been recognized in the sedimentary patterns of the Pontebba Supergroup. Detailed descriptions and columnar sections showing the cycles are found in recent papers (*e.g.* Venturini 1990, 1991; and especially Massari *et al.* 1991), although cyclic sedimentation was also stressed by previous authors.

As a whole, the Pontebba Supergroup is viewed as a late Hercynian transtensional pull-apart basin-fill, consistent with both the post tectonic relaxation of the very short emersion of the Palaeocarnic Chain (Vai 1976) and the late Carboniferous-early Permian trans-Variscan megashear (Arthaud & Matte 1977). It forms a composite sedimentary cycle defined by the Hercynian (Carnic) non conformity at the base and the mid-Permian (Saalic) disconformity at the top. This sedimentary cycle is notably distinct from the Permo-Triassic cycle and following ones by its smaller extent and different architecture in response to a different stress regime.

The most prominent character of this Permo-Carboniferous sedimentary cycle is that it is composed by a quite regular series of cyclothems having a mean thickness of about 30 m. Almost the same type of modal cyclothem is recognized in two different sedimentary environments. One, dominated by marine carbonate deposits (Pizzul and Auernig Formations, see below), starts with an unconformity by which progradation and shallow-marine coarse siliciclastic deposits rest on ramp sediments; a transgressive fine-grained highly fossiliferous clastic layer is closed by a limestone horizon followed by shallowing upward clastic sediments. The other one, domi-

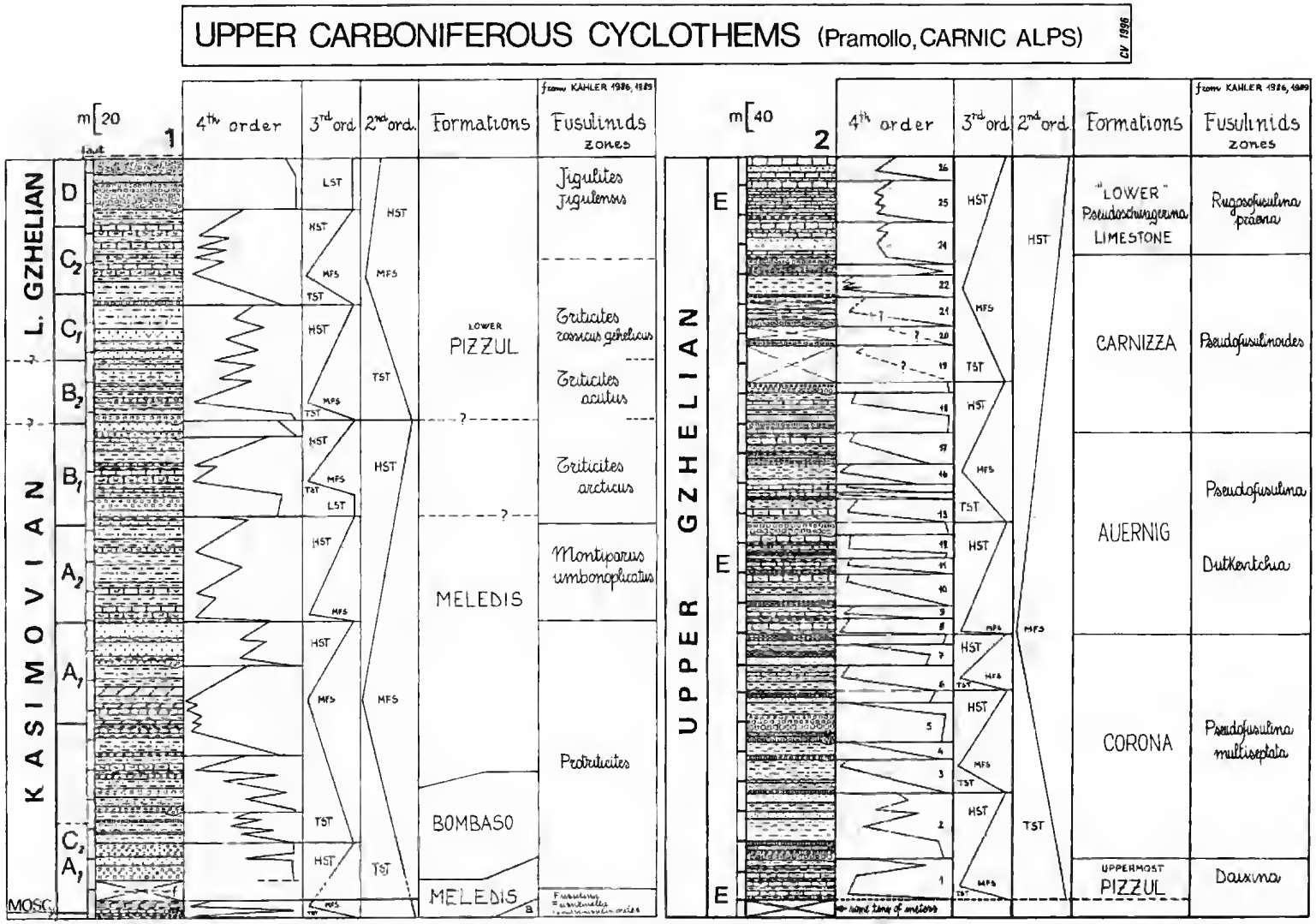


FIG. 1. — Third and fourth order lithocycles from the Carboniferous and earliest Permian of the Carnic Alps. Key: **LST-TST-HST**, low stand, transgressive and high stand systems tracts; **MFS**, maximum flooding surface; **B**, Bombaso Formation; the second column from left shows the stratigraphic subdivision according to the Austrian authors. Notice scale change from part 1 to part 2 of the section. See also legends in Appendixes 1, 2 and 3.

nated by more or less continental silicoclastics (Corona and Carnizza Formations), starts with superimposition of fluvial conglomerates on deltaic to coastal plain muddy sediments followed by fine-grained transgressive clastic ramp deposits and highstand fine silicoclastic marine bands. It follows that the upper Carboniferous cyclothems of the Carnic Alps can be described as high-frequency small-scale sequences in terms of sequence stratigraphy and depositional systems. Furthermore, the alternation of either carbonate or silicoclastic bundles suggests a climatic modulation of higher rank cyclicity in respect to that involved in the generation of cyclothems.

A similar, although more irregular and less studied cyclicity, is shown in almost all remaining late Carboniferous to early Permian Formations except the Trogkofel Limestone (and related units, see below).

Both larger and smaller-scale cycles recognized in the Pontebba Supergroup are closely similar to the classical Permo-Carboniferous cyclothems of North America, the Russian Platform, Western Europe and Africa (or to their internal subdivisions in formations and members). As an example, one can compare the impressive correspondence between the four Gzhelian formations of the Carnic Alps (Pizzul, Corona, Auernig and Carnizza) and the corresponding four Gzhelian "horizons" of the Russian Platform (Ross & Ross 1988: 234; Izart *et al.* 1995). On the other hand, similarly impressive is the almost perfect match between twenty-six cyclothems of the upper Gzhelian in the Carnic Alps (Fig. 1) and the twenty-one units of the roughly corresponding Virgilian in Kansas (Ross & Ross 1988: 233). The twenty-two cycles recognized within the Corona, Auernig and Carnizza Formations (Massari *et al.* 1991) added to the three out of the four cycles known in the "Lower" Pseudoschwagerina Formation (Homann 1969) altogether roughly correspond to the upper half of the Gzhelian, lasting as a whole stage about 5 Ma The ratio closely approximates the magic figure of 100 ka, which is thought to be the forcing orbital (short excentricity) factor of many depositional cycles (*e.g.* the glacial Pleistocene climatic-controlled paired Emiliani isotope "stages").

The cyclostratigraphic analysis of the Upper Carboniferous succession of the Pramollo Basin ("Auernig group" and its basal immature clastics, referred to as Bombaso Formation) deserves some additional remarks.

1. The Bombaso Formation is heteropic with both the Meledis Formation and the lower part of the Pizzul Formation (Venturini 1990, 1991). This is an effect of the Kasimovian synsedimentary tectonics, resulting in the uplift of a narrow Horst exposed to erosion. It lined up with the basin axis splitting it into two separated and independent Graben.

2. During late Gzhelian times the north-eastern Grabe, that is the well known area of Auernig, Carnizza and Corona Montains, was affected by strong tectonic subsidence. The sedimentation rate remarkably increased as compared to the previous Kasimovian-early Gzhelian figures (Venturini 1991).

It follows that, for a correct analysis of the cyclic upper Gzhelian succession, interfering of possible tectonic pulses must be carefully discounted from the effects of the glacio-eustatic oscillations.

The Permo-Carboniferous Pontebba Supergroup (Fig. 2)

For a better understanding of the palaeogeographic meaning of the Moscovian and Artinskian rocks exposed in the Carnic Alps, a summary about its almost continuous succession ranging from late Moscovian to early Kubergandian (in the eastern area) is useful.

The sequence starts with the fine clastic to carbonate mainly basinal Meledis Formation not conformably overlaying the Hercynian chain. The Meledis Formation often rests on a thin basal carbonate breccia body (Malinfier Horizon) and in some areas is laterally replaced by fault-scarp related plygenic breccias and immature coarse-grained siliciclastics (Pramollo Mb) named, as a whole, Bombaso Formation (Venturini 1990). The Meledis and Bombaso Fotmations span from the late Moscovian (Mjackovian) to the Kasimovian (*Protriticites* to *Montiparus* Zones). They are followed by the late Kasimovian to early Gzhelian (*Triticites, Jigulites* and *Daixina* Zones) Pizzul Formation, composed of outer shelf limestones and pelites alternating

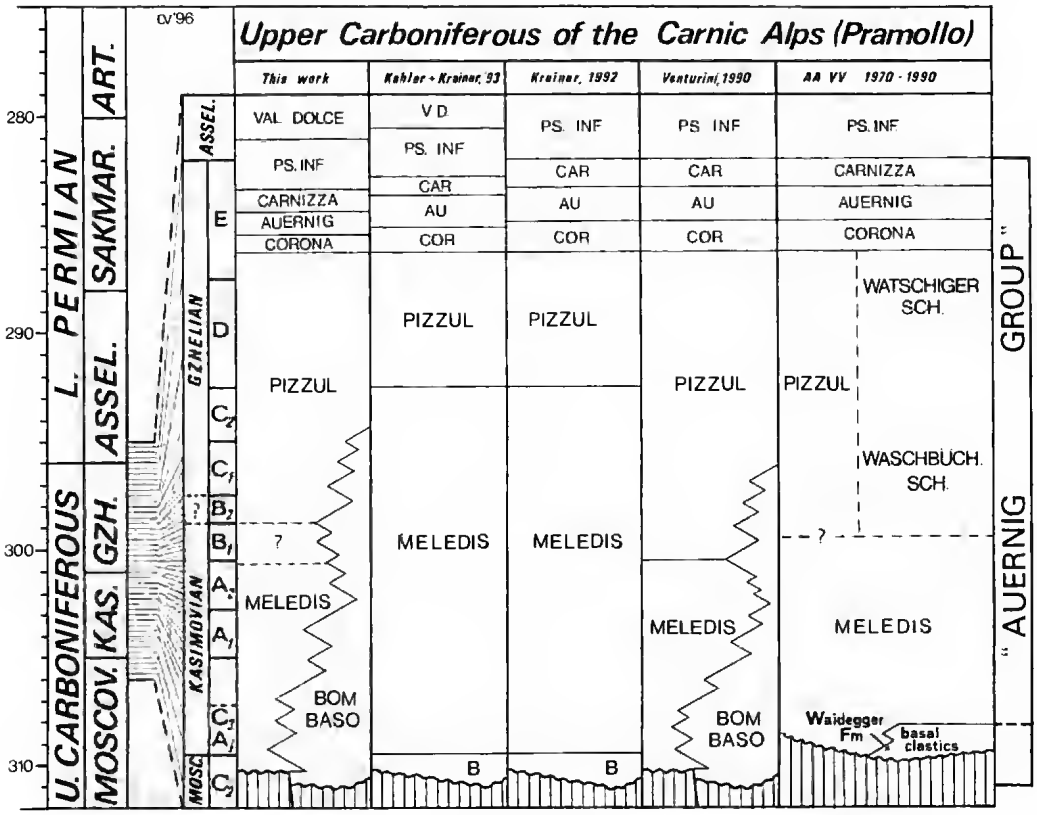


FIG. 2. — Lithostratigraphic subdivision of the Upper Carboniferous of the Carnic Alps. Key: **AU**, Auernig Fm; **B**, Bombaso Formation; **Cor**, Corona Formation; **PS. INF.**, "Lower Pseudoschwagerina" Formation; **V.D.**, Val Dolce Formation; the fifth column from left shows the stratigraphic subdivision according to the Austrian authors. See also legend in Appendixes 1, 2 and 3.

with coastal-deltaic coarse-grained clastics.

The Corona Formation of late Gzhelian (*Daixina* and *Pseudofusulina-Rugosofusulina* Zones) follows with fine-grained open shelf pelites (and a single limestone layer in the distal area) alternating with alluvial plain to deltaic conglomerates and sandstones (including some thin coal seems). The drastic decrease in carbonate productivity, without major change in physiographic conditions of the basin, suggest a marked temperate to cool climatic oscillation. This formation is characterized by 30 to 40 m thick cyclothems (parasequences).

The following Auernig Formation, of late Gzhelian age (*Pseudofusulina-Rugosofusulina* Zones) is composed by outer shelf marine carbonates and pelites alternating with coastal-deltaic coarse-grained clastics. This formation is characterized by cyclothems (parasequences) of mean thickness of about 20 m (range 15 to 40 m).

The Carnizza Formation closes the late Gzhelian (*Pseudofusulina-Rugosofusulina* Zones) and is made by outer shelf pelites and subordinate limestones alternating with coarse-grained sandstones and quartz conglomerates of deltaic environment.

The "Lower" Pseudoschwagerina Formation of latest Gzhelian to Asselian age (*Schwagerina* Zone) is composed of massive to bedded shallow-water limestones interlayered by fine-grained marine silicoclastic sediments. Four cyclothems have been recognized (Homann 1969) and recently analysed (Samankassou 1995). The Val Dolce Formation of Asselian age (*Schwagerina*

Zone) is dominated by tetrigenous deposits with minor limestone intercalations (like in most of the late Carboniferous) representing delta to prodelta sequences.

Traditionally, the Carboniferous/Permian boundary was placed between the Carnizza and the "Lower" Pseudoschwagerina Formations. More recently a position inside the "Lower" Pseudoschwagerina Formation at the base of the *Occidentoschwagerina alpina* Zone was suggested (Kahler & Krainer 1993). Lately, Davydov & Kozur (1995) have proposed an even higher place at the base of the Val Dolce Formation (Grenzlandbänke). Waiting for further taxonomic precision we adopt here a boundary place still within the "Lower" Pseudoschwagerina Formation inside the not yet investigated interval above sample SK115 of Kahler & Krainer (1993).

The "Upper" Pseudoschwagerina Formation of late Asselian to early Sakmarian age (*Zellia* Zone; Forke 1995) is composed of alternating massive reefal and bedded partly marly inner shelf limestones.

The following Trogkofel Limestone (Sakmarian, *Robustoschwagerina* and *Pseudoschwagerina* Zones) and the following related Tressdorfer Limestone (early Artinskian, *Pamirina* Zone) and Coccau (= Goggau) Limestone (mid to late Artinskian, *Misellina* Zone) represent as a whole a reef-complex of shelf and shelf-edge environment, which has been compared with the Capitan Reef of Texas (Flügel 1981).

THE MOSCOVIAN OF THE CARNIC ALPS (Fig. 3)

Only the late Mjackovian substage of the Moscovian is certainly represented in the early lithostratigraphic units not conformably overlying the severely folded and thrusted Palaeocarnic Chain. The lowermost fusulinids found above the unconformity are representative of the *Protriticites* Zone and include *Eostaffella*, *Paraendothyra*, crinoids, brachiopods, echinoids, molluscs, bryozoans, trilobites and phylloid plus dasycladacean algae (Kahler & Prey 1963; Selli 1963; Pasini 1963, 1974; Vai *et al.* 1980; Venturini 1990). The stratigraphic units bearing this fauna are the Malinfier Horizon (matrix), the Meledis Formation and its lateral equivalent Pramollo Mb (matrix) which have been referred to above. Consistent with the above dating are also macrofloral and palynomorph data. In fact, ferns (*Neuropteris* ex gr. *ovata* = *grand'euryi*) of Cantabrian age (late Moscovian to early Kasimovian) occur at the top of the Meledis Formation (Vai *et al.* 1980). Also the palynomorphs of the lowermost Bombaso Formation (Francavilla 1966), dated at the Westfalian B or so (early Moscovian), are consistent with the age of the first fusulinids. It suggests also a possible earlier Moscovian onset of the post-tectonic sedimentation of the Pontebba Supergroup.

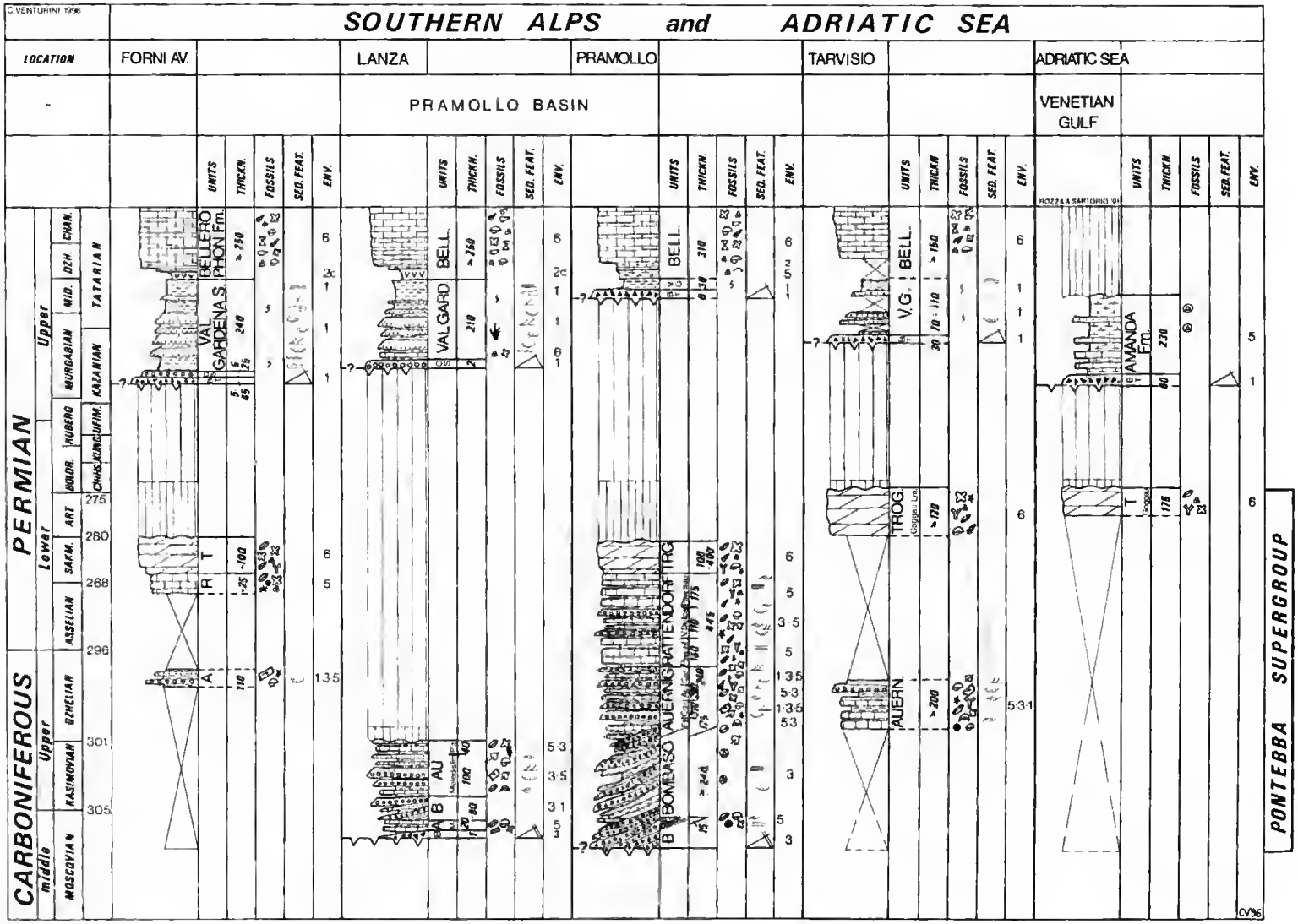
The major faunal affinities are found between Carnic Alps, the Dinarides and the Russian Platform to Urals. Floral relationships are more close with the Cantabrian region than with NW Europe. Recent finding of Kasimovian conodonts suggests close affinity with Chinese elements (Perri & Spalletta, pers. comm.; see also Forke 1995).

THE ARTINSKIAN OF THE CARNIC ALPS (Fig. 3)

On top of the 150 to 400 m thick Trogkofel Limestone (a complex system of *Tubiphytes* buildups) of Sakmarian age, in places of the "middle" Permian reef-complex, some limestone masses escaped the Saalic uplift and erosion, showing remnants of the Artinskian stage *l.s.*

The lower Artinskian is represented directly by the Tressdorfer Limestone (15 m thick). It is made of mainly brecciated shallow-water limestone with both extraformational (reworked from the underlying Trogkofel and "Upper" Pseudoschwagerina Formation) and autochthonous components rich in *Mizzia*, other algae, gastropods, fusulinids, other foraminifera, pelmatozoans and bryozoans. It contains sometimes *Praeparafusulina lutugini* which is an element of the Russian *Pseudofusulina lutugini* Zone. A quite

FIG. 3. — Stratigraphic correlation of the main Moscovian to Artinskian columnar sections of the southern Alps (exposures) and the Adriatic Sea (subsurface) and their interpretation (chronometric calibration of the chronostratigraphic scale conforms to that discussed in the first part of the paper). Key: **A**, Auernig; **B**, Bombaso; **B.T.**, Tarvisio Breccia; **C.S.**, Sesto Conglomerate; **M**, Meledis; **Piz**, Pizzul; **T-TROG**, Trogkofel; **R**, Rattendorf; **V.G.**, Val Gardena; **Bell.**, Bellerophon. See legend in Appendixes 1, 2 and 3 for other symbols.


C.VENTURINI 1996
SOUTHERN ALPS and ADRIATIC SEA
LOCATION
FORNI AV.
LANZA
PRAMOLLO
TARVISIO
ADRIATIC SEA
PRAMOLLO BASIN
VENETIAN GULF
UNITS
THICKN.
FOSSILS
SED. FEAT.
ENV.
PERMIAN
CARBONIFEROUS
Upper
Lower
middle
CHAN.
DZH.
MID.
MURGABIAN
KUBERG
BOLDR.
ART
SAKM.
ASSELIAN
GZHELIAN
KASIMOVIAN
MOSCOVIAN
TATARIAN
KAZANIAN
UFIM.
KUNG.
CHHS.
275
280
268
296
301
305
BELLERO PHON Fm.
VAL GARDENA S.
BELL.
VAL GARD
AU
BOMBASO
AUERNIG
RATTENDORF
TRG
V.G.
TROG.
AUERN.
AMANDA Fm.
PONTEBBA SUPERGROUP
CV96

effective pre-late Kubergandian erosion is suggested by the frequent occurrence of Tressdorfer- and Trogkofel Limestone blocks in the late Kubergandian to Murgabian Tarvisio Breccia (Fig. 3).

The upper Artinskian is represented by the Coccau Limestone. This is a light grey massive shallow-water limestone quite similar to the previous two formations. In its upper part a rich fusulinid fauna from the *Pseudofusulina vulgaris* Zone, including *Pamirina darvasica*, *Minojaponella elongata* and *Nagatoella* aff. *orientis* is found, suggesting an age from Artinskian to early Bolorian or early Kungurian, at the very base of the *Misellina* Zone (Kahler 1992).

The Artinskian of the northern Adriatic Sea (Fig. 3)

The age assigned to the Coccau Limestone above was confirmed recently from the Amanda 1 well drilled by AGIP about 50 km E of Venice (45°24'47"N - 13°00'38"E). The Permian, beneath the mid Triassic Latemar Formation (late Anisian-Ladinian), was encountered from 6840 to 7305 m depth (Sartorio & Rozza 1991). It is represented from the top by:

1. The Amanda Formation, dark to reddish marls, clay, silty sandstones with palynomorphs, some carbonate intercalations with fusulinids (*Kahlerina pachytheca* of the *Neoschwagerina* Zone), foraminifera and algae (*Tubiphytes*) and fine breccias representing the late Permian (possibly late Kubergandian to Murgabian).

2. The Tarvisio Breccia, composed of reworked clasts from the underlying Coccau (= Goggau) Limestone and a red clayey matrix, deposited in a subaerial environment.

3. The 175 m thick Coccau Limestone, represented here mainly by shallow-water platform rudstone and grainstone facies, including rich fusulinid fauna (*Pseudofusulina*, *Praeparafusulina*, *Acervoschwagerina*, *Misellina*), foraminifera, algae (*Tubiphytes*, *Archaeolithoporella*), bryozoans, brachiopods, pelmatozoans, bivalves, ostracods and rare *Bellerophon*. The core taken from the middle part of the formation was assigned to the *Misellina claudiae* Zone of the latest early Permian (Chihsianskian or equivalents).

Final remarks

The correlation chart in figure 3 shows two major stratigraphic cycles easily traced along the entire western Adriatic and eastern Southalpine areas. The first one, represented by the Pontebba Supergroup, starts with the late Moscovian and lasts at least up to the entire Artinskian and part of the Bolorian. It is mainly marine, with continental clastic supply strongly decreasing upwards and dominated by western provenance. Thalassocratic conditions culminate with the early Permian, especially Sakmarian to Artinskian. It is followed by a remarkable, general although differential uplift and erosion, occurring sometimes during the late Bolorian to Kubergandian interval. How much the relative uplift is to be related to a concurrent eustatic sea level drop could be argued only upon establishment of more reliable sea level curves for the Permian. The second cycle begins with the early Murgabian spanning the Permo-Triassic boundary, except for the Venetian Gulf area showing late Permian/early Triassic uplift. This is a broadly transgressive cycle dominated by the flood plain Val Gardena Formation evolving to the Bellerophon sebkhas and shelf. This trend is quite contrasting with the more common worldwide Permian regression.

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APPENDIX 1: KEY TO FOSSIL AND SEDIMENTARY STRUCTURE SYMBOLS

FOSSILS

- Acritarchs, Chitinozoa
- Algae
- Ammonoids, Nautiloids
- Amphibians
- Bivalves
- Brachiopods
- Brachiopod spine
- Bryozoans
- Charophytes
- Conchostracans
- Conodonts
- Corals
- Crinoids
- Echinoderms
- Fishes
- Fish teeth
- Foraminifera (benthic)
- Foraminifera (planktic)
- Foraminifera (indet.)
- Fusulinids
- Gastropods
- Graptolites
- Insects
- Nannofossils
- Orthocones
- Ostracodes
- Palynoflora
- Plantae (wood)
- Plantae (leaves)
- Radiolarians
- Reptiles
- Sponges
- Sponge spicules
- Stromatoporoids
- Tetrapod foot prints
- Trilobites
- Vertebrate teeth
- Vertebrate bones
- Shells indet.
- Bioclasts indet.

SEDIMENTARY STRUCTURES

- Bioturbation
- Large scale cross bedding
- Small scale cross bedding (r: ripple)
- Parallel bedding
- Lamination
- Channel
- Slump
- Tempestite

Appendix 2: Columnar section legend

MAIN COLUMN
DEPOSITIONAL ENVIRONMENT

1	Continental, Lacustrine orange	6	Shallow carbonates gold yellow
2	Evaporites pink	7	Pelagic rise olive green
3	Deltaic pale yellow	8	Deep carbonates light blue
4-5	Shallow marine clastics green		Erosional hiatus
9	Deep marine clastics blue		Non-depositional hiatus
10	Deeper marine clastics brown		Lack of data

LITHOLOGY

▲ ▲ ▲ Breccia

Sand, conglomerate

Sand

Sand, silt, shale

Carbonate, sand

Carbonate
- p=packstone
- g=grainstone
- w=wackestone
- m=mudstone

Reefal carbonate, bindstone

Carbonate, shale

Pelagic carbonate

Nodular carbonate

Shale, some carbonate

Shale

Turbidites
- s=silicoclastic
- v=volcanoclastic
- c=carbonate

Organic shale

Dolomite

Sulphate

Halite

Coal

Chert, radiolarite

Volcanics

Volcanoclastic deposits

Concretion (Fe: iron, etc.)

- O Oolite
- P Phosphate
- B Bauxite
- Pa Paleosol
- ● Oil, gas

SIDE-COLUMN

Erosion, unconformity

Low / High angle unconformity

R W Rift / Wrench induced

I F Inversion, folding

TR RE Transgression, regression

U C Regional uplift / collapse

M★ ✚ Metamorphic, volcanics, intrusives

Appendix 3: Map legend

DEPOSITIONAL ENVIRONMENT AND MAIN LITHOLOGY

- 1 — Mainly continental clastics orange (c=coarse; f=fine; l=lacustrine, d=desertic, lateritic)
- 2 — Evaporites pink (t=and clastics; c=and carbonates)
- 3 — Deltaic shallow marine, mainly sands pale yellow
- 4 — Shallow marine, mainly shales pale green
- 5 — Shallow marine, carbonates and clastics green
- 6 — Shallow marine, mainly carbonates gold yellow
- 7 — Pelagic rise olive green
- 8 — Deeper marine carbonates light blue
- 9 — Deeper marine clastics blue
- 10 — Deeper marine, mainly sands (turbidites) light brown
- 11 — Basins floored by oceanic lithosphere dark blue

TECTONIC SETTING AND LITHOSPHERIC TYPE

- 12 — Foreland
- Foredeep basin
- Normal lithosphere
- Active fold belt — Thick lithosphere
- 13 — Inactive fold belt
- 12 — Anorogenic craton
- Normal lithosphere
- Rift
- Thin lithosphere
- 11 — Oceanic lithosphere dark blue

VOLCANIC ACTIVITY

- 15 — Basaltic plateau dark red
- 16 — Porphyric plateau light red
- ★ Anorogenic
- ☆ Orogenic

AUXILIARY SYMBOLS

- Fault, wrench, normal
- 1 2 — Major thrust fault 1 active, 2 inactive
- 1 2 B A — B and A subduction 1 active, 2 inactive
- Accretion wedge
- Major anticlinal axis
- Isopach of the ..... (stage)
- Basin margin
- Direction of clastic influx
- Limit of palaeoenvironment
- Continental slope
- Active sea-floor spreading axis and transform fault
- As above, with magnetic anomaly

Review and updating of the Moscovian to Artinskian marine rocks in peninsular Italy

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KEY WORDS
Bashkirian,
Vereyan,
Kashirian,
Podolskian,
Bolorian,
Kubergandian,
fusulinids,
conodonts,
corals,
Tuscany,
Lucania,
Apulia,
Apennines.

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ABSTRACT
New and previous data on the mainly marine Carboniferous to Permian sequence of the Apennine Chain and its foreland in Italy (especially Tuscany plus Lucania and Apulia) are summarized. Of special interest is the restored correlation between a shallow-water carbonate platform and the related basin with turbidites and olistostromes, pointing to the Hercynian outer foredeep tectofacies.

MOTS CLÉS
Bashkirien,
Vareyen,
Kashirien,
Podolskien,
Bolorien,
Kubergandien,
fusulines,
conodontes,
coraux,
Toscane,
Lucanie,
Apulie,
Apennins.

RÉSUMÉ
Nous résumons ici les données, nouvelles et anciennes, qui concernent des dépôts, principalement marins, du Carbonifère au Permien des Appennins et de son avant-pays italien (particulièrement la Toscane, la Lucanie et l'Apulie). On notera tout spécialement l'établissement d'une corrélation entre des carbonates de plate-forme peu profonde et les turbidites et olistostromes liées au bassin adjacent, qui illustrent la tectonofaciès de l'avant-fosse hercynienne externe.

Moscovian and Artinskian units are emphasized here within the frame of Carboniferous to Permian sequence of rocks.

MOSCOVIAN (Fig. 1)

Fossiliferous marine sedimentary rocks datable to the Moscovian outcrop only in a narrow area of the northern Apennines, between Siena and Grosseto (Monticiano-Roccastrada area, Tuscany). Two main sequences have been separated (Cocozza *et al.* 1987): a northern one along the Farma river and a southern one in the San Antonio mine area.

The Farma river sequence, between Contrada Carpineta and 170 m a.s.l., near Iesa (43°5'N - 11°16'E) includes: (1) the Risanguigno formation containing Devonian silicified limestone (Bagnoli & Tongiorgi 1980); (2) a chert formation (lyditic radiolarites) of possible Dinantian age; (3) the Carpineta formarion (Cocozza *et al.* 1974) of late Viséan to Moscovian age; and (4) the Farma formation (Cocozza *et al.* 1974) of late Bashkirian to late Moscovian age. This sequence, severely tectonized and largely overturned, is unconformably overlain by the Permo-Triassic Verrucano Group (Cocozza *et al.* 1974; Conti *et al.* 1991). Of major interest are the Carpineta and Farma formations.

The Carpineta formation, mainly shaly and silty with brachiopods, bivalves and plant debris, contains olistolithic intercalations of limestone rich in crinoids, algae and foraminifera. Brachiopods suggest a late Viséan to early Namurian age (Pasini & Winkler-Prins 1981) as well as the Archaediscidae found in the sandy-silty layers (Pasini 1980b). However, the foraminifera from the limestones suggest a late Bashkirian to early Moscovian age (Pasini 1978, 1980a).

The Farma formation is a thin bedded siliceoclastic turbidite with few interposed limestone olistostromes and olistoliths. Limestones contained in the lower part of the formation and probably identical to the San Antonio limestone formation (see below) have been dated to the late Bashkirian-late Moscovian (Podolskian to Mjackovian substages) by Ferrari *et al.* (1977) and Pasini (1978, 1980a). More precisely, Ferrari *et al.* (1977) reported two different foraminiferal faunas from the limestone olistostromes and from a loose dark limestone boulder: the first one, with *Profusulinella* and *Pseudostaffella*, was assigned to the zone 22 (or slightly younger) of Mamet, which is late Bashkirian to early Moscovian; the second one was tentatively assigned to the late Moscovian: Corals (*Spirophyllum multilamellatum* de Groot) and conodonts (*Idiognathodus delicatus* Gunnell) yielded in the same boulder were assigned an early Moscovian and a late Moscovian age respectively.
Limestones from the upper part of the Formation show *Fusiella praetypica* Safonova of the Podolskian substage (late Moscovian). The Farma formation is more than 500 m thick (Conti *et al.* 1991).

The San Antonio mine sequence is located near Casal di Pari (Grosseto) (43°3'N - 11°17'E) and include: (1) the Carpineta formation (lacking olistolithic inclusions here); (2) the San Antonio limestone formation, 200 m thick, of late Bashkirian to early Moscovian age; (3) the paleosol horizon with bauxite; and (4) the Spirifer shales (Cocozza 1965) of late Moscovian (Mjackovian) to early Cantabrian age, which are exposed for 2 m only.

The San Antonio limestone formation is a dark to black, shallow-water, bioclastic limestone, partly dolomitized. It contains algae and foraminifera with fusulinids (*Ozawainella* ex gr. *O. grandis* Putrja)) of early Moscovian (Vereyan to Kashirian) age.
The Spirifer shales contain *Pseudostaffella* cf. *sphaeroidea* (Ehr.) and brachiopods of latest Moscovian-earliest Cantabrian age (Pasini 1980a).

The Farma sequence is entirely basinal and shows a systematic deepening of the sedimentary environment. The San Antonio sequence suggests an almost steady outer shelf environment with a short emersion disconformity in the late Moscovian. Large parts of the two sequences are time overlapping. Both contain the

Pseudoendothyra-Pseudostaffella association which supports a close relationship also suggested by olistostromes and olistoliths supplied from the shelf to the basin.

ARTINSKIAN (Fig. 1)

Clear fossil evidence of marine Artinskian rocks in peninsular Italy was only found in the well PC/33b (42°50'50"N - 11°41'30"E) drilled by ENEL Co. on the Mt. Amiata (southern Tuscany). This well cored fossiliferous carbonate layers, containing fusulinids from – 3024.40 to – 3028.40 m beneath the surface. The core was made up of five elements, the deeper of which included *Praeparafusulina* cf. *lutugini* (Schellw.) and *Eopolydiexodina* sp.; therefore it was referred to the *P. lutugini* Zone of the Artinskian. Higher elements of the core, however, yielded fusulinids assigned to the genera *Cancellina*, *Yangkienia* and *Pseudodoliolina*, which have been referred to the Kubergandian.

The cored interval thus seems to represent a condensed Artinskian to Kubergandian sequence (Pandeli & Pasini 1990). The lack of fossils within the drilled deeper levels prevent an assessment of the total thickness of the Artinskian sediments.

The Palaeozoic sequence found in the well PC/33b is composed by the "A", "B" and "C" formations (Fig. 1), among which the "B" formation is viewed as a tectonic wedge of pre-Viséan age within the "A" formation. This

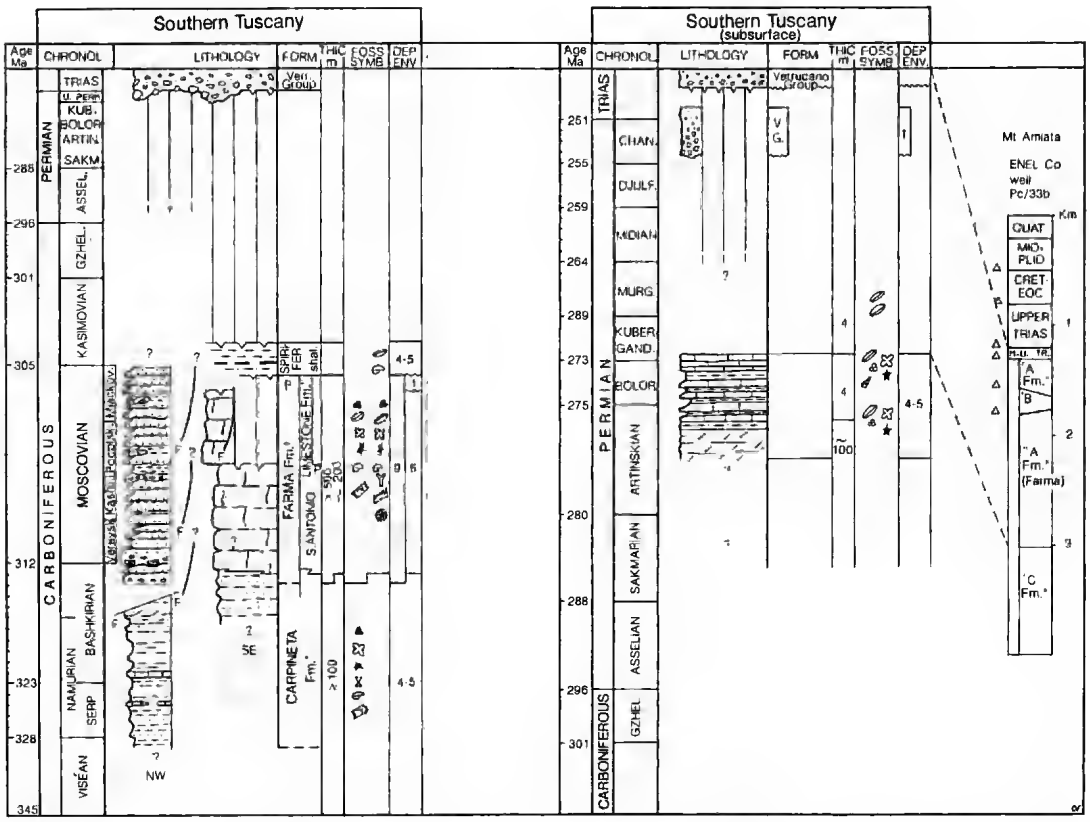

FIG. 1. — Mid to late Carboniferous, mainly Moscovian, stratigraphic sections in southern Tuscany and their interpretation (left); late early Permian stratigraphic section from the Southern Tuscany subsurface and their interpretation (right). See Vai & Venturini (this volume) for legend; F, fault.

sequence is unconformably overlain by the (?) Triassic Verrucano Group, and was interpreted as a reverse-recumbent fold or a complex pile of Alpine tectonic wedges (Conti *et al.* 1991).

RELICS OF THE MARINE PERMIAN

This is a review of subsurface, poorly exposed, or indirect evidences of Permian marine rocks in peninsular Italy.

Poorly exposed marine sediments of probable Artinskian age are represented by small carbonate lenses with rare fusulinids (*Parafusulina* of earlier type) (Bodechtel 1964; Kahler 1969), crinoids molluscs brachiopods and plant debris enclosed in the mostly marine Rio Marina formation of Westfalian/Stephanian to early Permian age, Elba Island (42°49'N - 10°26'E; Vai 1978).

Rare relics of uppermost Carboniferous to lowermost Permian with fusulinids and algae have been found as clasts within the middle Triassic Mt. Quoio Formation, Verrucano Group, southern Tuscany (43°6'N - 11°12'E; Engelbrecht *et al.* 1988).

Other relics are found in the middle Triassic Mt. Facito Formation, southern Apennines, near Potenza (40°28'N - 15°42'E; 40°12'N - 15°50'E; Donzelli & Crescenti 1970). Fusulinids and smaller foraminifera of late Permian (Murghabian to Dzhulfian age) are contained in resedimented conglomerates in the lower part of the formation (Panzanelli-Fratoni *et al.* 1987; Ciarapica *et al.* 1990). Rare Artinskian fusulinids (*Pamirina darvasica* Leven) are also found besides the late Permian microfauna (Pasini, unpublished data).

A possible source area for the Mt. Facito resedimented Permian conglomerates may be found in the poorly fossiliferous cuttings from the 4581-4698 m interval drilled by Conoco in the Gargano 1 well in 1984 (41°50'46"N - 15°24'30"E). It is composed of light grey limestone containing fusulinids of late Carboniferous to Permian age underlying a thick Jurassic and Triassic sequence.

Consistent with the above assumption is also the late Permian of the Apulia subsurface. A mainly continental alluvial plain sedimentation of late Permian age (equivalent to the Southalpine Val Gardena Formation) containing some coastal lagoonal carbonate deposits in the latest Permian was drilled by Agip in the Puglia 1 well (41°3'30"N - 16°5'30"E).

The data discussed suggest a coherent picture of a mainly marine foredeep to foreland deposits punctuating the Carboniferous to Permian interval in the wide palinspastic space hidden in the present Italian peninsular area.

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Permian deposits of Sicily: a review

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ABSTRACT
The complex tectonostratigraphic setting of the Permian rocks of Sicily is outlined in the light of the large mass of new stratigraphic and paleontologic data recently collected by several researcher groups. The Permian deposits occur mostly as tectonic *mélanges* imbricated in the thrust pile forming the Sicilian fold and thrust belt. Also Mesozoic and Tertiary uncompetent rocks can be found in these *mélanges*. Several lithostratigraphic units were differentiated among these mostly siliciclastic and clastic-carbonate deep-water deposits, spanning in age from Kungurian up to Changxingian. The Permian deposits are regarded as the originary sedimentary substrate of the deep-water mesocenozoic domains of Sicily. Fossil associations, facies and ages of these deposits are consistent with the existence of a wide and persistent deep-water basin located along the Africa margin since, at least, the early Permian time and connected to the main Tethyan domains.

KEY WORDS
stratigraphy,
paleogeography,
Permian,
western Sicily.

RÉSUMÉ
L'arrangement tectonostratigraphique complexe du Permien de la Sicile est défini à partir de nombreuses données stratigraphiques et paléontologiques récemment collectées par différents groupes de chercheurs. Les dépôts du Permien surviennent le plus souvent comme des mélanges tectoniques, avec quelquefois des roches mésozoiques et tertiaires, imbriqués dans des piles d'unités tectoniques formant la chaîne sicilienne. Plusieurs unités lithostratigraphiques, principalement constituées de dépôts silicoclastiques et clastiques-carbonatées de mer profonde, datées du Kungurien au Changxingien, ont été différenciées. Ces dépôts constituent le substrat sédimentaire des bassins méso-cénozoiques de la Sicile. Les associations de fossiles, le faciès sédimentaires et l'âge des terrains permiens indiquent l'existence d'un bassin ample et persistant, localisé le long de la marge africaine depuis, au moins, le Permien inférieur et relié avec les principaux domaines téthysiens.

MOTS CLÉS
stratigraphie,
paléogéographie,
Permien,
Sicile occidentale.

INTRODUCTION

In the Sicilian fold and thrust belt strongly tectonized Permian-Triassic deep-water deposits occur as either duplexes or *mélanges* imbricated with tectonic units of basin-derived Mesozoic and Tertiary rocks. A large amount of new stratigraphic data was collected in this last decade from these deposits, poorly exposed in the Lercara region and in the Sosio Valley (Catalano, Di Stefano & Kozur 1988, 1989, 1991 and references therein, 1992; Senowbari-Daryan & Di Stefano 1988; Kozur 1989a, b, 1991a, b, 1993a, b; Kozur & Mostler 1989; Di Stefano 1990; Flügel, Di Stefano & Senowbari-Daryan 1991 and references therein; Gullo & Kozur 1992). Some new lithostratigraphic units were differentiated. New Lower and Middle Triassic rock units were described from the Sosio Valley. Also the stratigraphic and paleoenvironmental evaluations of the famous Sosio Limestones (Gemmellaro 1887-1899) were revised (Di Stefano 1990; Flügel *et al.* 1991).

Figure 1 is a simplified structural sketch-map of Sicily showing the location of the geologic section in figure 2 and of the stratigraphic columns in figure 4: a = Lercara-Roccapalumba-Vicari area; b = Sosio area.

GEOLOGIC SETTING

The Permian rocks from the Lercara and Sosio Valley areas are incorporated in the Sicanian thrust system, an external element of the Sicilian chain (Catalano *et al.* 1993, 1995). This tectonic element consists of basin-derived thrust sheets that are arranged with an overall foreland vergence and minor back thrusts (Sicanian units in Figs 1, 2). The Sicanian thrust system is buried in central Sicily beneath a thick allochthon consisting of deformed foreland and satellite-basin deposits of Neogene age and outcrops again in eastern Sicily in the Mount Judica area. It overthrusts southwards more external platform-derived tectonic units (Saccense-Hyblean units) as well as the deformed syntectonic covers (Fig. 2). The Sicanian thrust sheets are derived from the deformation of a sedimentary multilayer, consisting of up to 2000 m of Upper Paleozoic to Tertiary deep-water deposits that accumulated in a southern Tethyan domain loca-

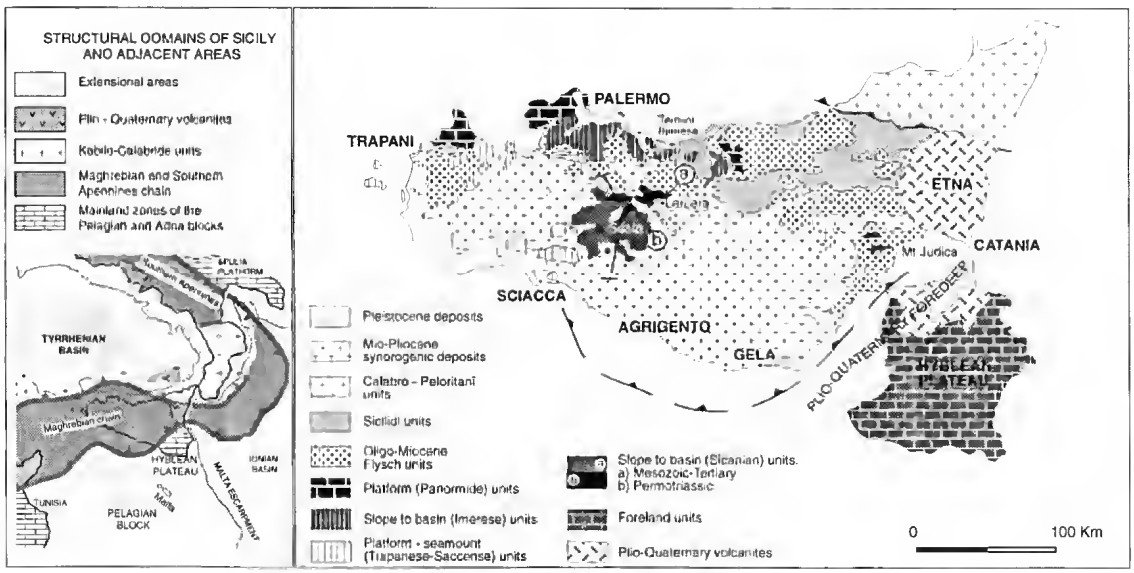

FIG. 1. — Main structural domains of the central Mediterranean area and structural sketch of Sicily (modified from the Structural Model of Italy sheet No. 6).

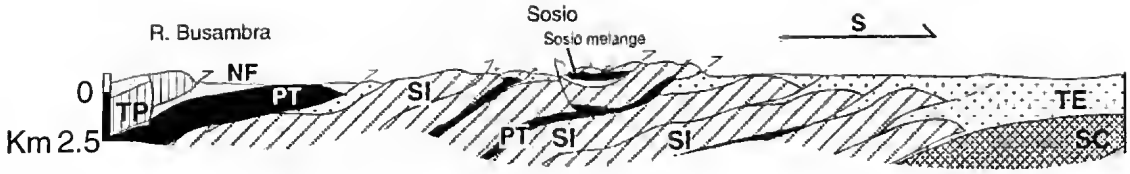

Fig. 2. — Interpretative geologic section across the Rocca Busambra-Sicani Mountains area based on surface data (location in Fig. 1): **TP**, Trapanese units (Late Triassic-Miocene); **NF**, Numidian Flysch units (Late Oligocene-Early Miocene); **SI**, Sicanian units (Late Triassic-Early Tertiary), **PT**, Permian-Carnian units; **SC**, Saccense units (Late Triassic-Miocene); **TE**, Oligo-Miocene, mostly terrigenous, deformed covers. The thick allochthon of Permian-Carnian deposits dipping below the Rocca Busambra Unit represent the westward extension of the Lercara structure.

ted along the African margin (Sicanian Basin, *sensu* Di Stefano 1990, Catalano *et al.* 1991). Because of the Neogene compression this multilayer was detached from its original (unknown) substrate. According to Catalano *et al.* (1993, 1995), it was deformed into three different duplex stacks consisting of Paleozoic-Carnian, Late Triassic-Paleogene and Neogene rocks respectively.

In the Lercara area the Permian rocks occur in a large antiformal structure, up to 3000 m thick, consisting of Permian and Triassic rock slices alternating, in places, with thin slices of Miocene clays. The extension at depth of the structure is documented by seismic and exploration well data (Roccapalumba 1 well, Caflisch & Schmidt di Friedberg 1967). The repeated imbrication of Permian and Triassic rocks in the Lercara structure provides evidence of a duplex-type deformation in the Permian to Carnian interval of the Sicanian sedimentary multilayer. The first deformation of the Sicanian allochthons is generally considered to be no older than Tortonian (Mascle 1979; Catalano & D'Argenio 1982) even though a possible older age (Lower Miocene) for the duplex accretion was suggested by Vitale & Giambrone (1992). The Lercara structure is inflected northwards below Numidian Flysch units as well as Trapanese platform units and overthrusts southwards more external Sicanian allochthons (Fig. 2). The upward-arching and emplacement of the structure is due to later (Pliocene) transpressional deformation as indicated by the involvement of the Upper Tortonian-Lower Pliocene syntectonic covers in arching as well as in breaching thrusts.

In the Sosio area the well-known Permian limestone megablocks (Gemmellaro 1887) were considered sedimentary klippen in Carnian beds (Mascle 1979). We now believe that the Permian to Carnian rocks outcropping in this area, comprising the Permian to Middle Triassic deposits described by Catalano *et al.* (1988, 1991), are part of a tectonic *mélange* (here indicated as Sosio mélange), which is related to the Neogene compression and imbricated in the Sicanian thrust pile (Fig. 2). This *mélange*, up to 500 m thick, indicates *décollement* or floor-thrusts along which the Late Triassic-Tertiary sequences have been detached from the Permian-Triassic substrate. It overthrusts the Oligo-Miocene deformed cover of a lower unit and is overlain by a duplex structure composed of Upper Triassic-Eocene cherty limestones.

Besides the Lercara and Sosio areas, siliciclastic deposits of supposed Permian age, containing elements of algal-oolitic limestones, were described in the Cozzo Rasolocollo area, south of Termini Imerese (Broquet 1968). Until now no biostratigraphic data confirming a Permian age have been obtained from these rocks. They form, together with Carnian *Halobia*-bearing marls and calcilutites, a thick allochthon crossed by the exploration well Cerda 1 for about 3300 m. According to Rocco & Giartosio (1961) evidence of Permian rocks could be found only in the deepest part of this well.

Permian and/or Lower Triassic rocks could also be present in the subsurface of the Hyblean foreland, in south-eastern Sicily, as suggested by magnetic and gravimetric data (Bianchi *et al.* 1989).

PERMIAN LITHOSTRATIGRAPHIC UNITS

The stratigraphic reconstruction of the Permian successions from the Lercara and Sosio areas is very difficult due to:

1. The strong deformation affecting these mostly incompetent rocks.

2. The poor exposures: only a few small and discontinuous sections can be observed.

3. The facies types, which consist of mostly siliciclastic/carbonate turbidites containing a large mass of reworked lithoclastic and bioclastic material.

4. The lack of stratigraphic relations among the different lithologic units, the contacts generally being tectonic.

Aware of the above limitations which have led to debate about the age of the siliciclastic rocks of the Lercara area (*see* Ruggieri & Di Vita 1972; Cirilli *et al.* 1990), we recognize the following lithostratigraphic units, whose thickness is quite impossible to be estimate. In figure 4 we have preferred to present the different rock units in separate columns, but we believe they belong to different depositional areas of a single sedimentary basin. The Permian chronostratigraphic scale of Kozur (1989a, c) is used, tentatively correlated with the proposed time scale adopted for the Peri-Tethys program and map.

KUNGURIAN FLYSCH (Catalano *et al.* 1991)

This is the oldest Permian lithostratigraphic unit. It was recognized in the Roccapalumba, Lercara and Vicari areas and consists of a thick package of deep-water siliciclastic turbidites characterized by reddish shales, siltstones and micaceous sandstones displaying Bouma divisions, flute casts and *Nereites* ichnofacies. The sandstones contain abundant quartz and muscovite and subordinate biotite, feldspars and rare zircons (Broquet 1968). A Late Artinskian-Kungurian age of these deposits is supported by conodonts (Catalano *et al.* 1991). Calcareous turbidites are frequently interbedded. They consist of skeletal-lithoclastic grainstones/packstones with fusulinids, *Tubiphytes* sp., *Archaeolithoporella* sp., dasycladacean algae (*Mizzia* sp., *Epimastopora* sp.) and sponge fragments.

Magmatic rocks (diabases and lamprophyres) are present in the flysch deposits. Also a small laccolitic body consisting of a sodic-differentiated alkali-syenite is present in the Torrente Margana area, about 10 km west of Lercara (Vianelli 1970). No age determinations of these magmatic rocks are available. They could also be younger than Permian.

Intercalations of coarse calcareous debrites in the siliciclastic turbidites also occur in places. A large spectrum of facies-types can be recognized in the debrite elements. Shallow-water pebbles and boulders consisting of sponge/*Tubiphytes* boundstones, *Tubiphytes/Archaeolithoporella* bindstones, phylloid algae boundstones, *Mizzia*-fusulinid grainstones-packstones, and crinoidal packstones are commonly found (Senowbari-Daryan & Di Stefano 1988). A Lower Permian age of these elements is indicated by algal assemblages and fusulinids as *Pseudofusulina (Leeina) kraffti* Schellwien and *P. vulgaris* Schellwien (Flügel *et al.* 1991).

Large boulders of deep-water dark-grey ammonoid-brachiopod-crinoidal bearing wackestone-packstone are also present, in unclear relationships with the flysch deposits. Conodonts of Chihsian age were found associated to albaillellacea radiolarians, ammonoids, scolecodonts, linoproductid brachiopods and trilobites (Catalano *et al.* 1991).

Younger Permian rock packages are exposed in the Sosio Valley area, along the Torrente San Calogero (Catalano *et al.* 1988, 1989, 1991, 1992) as well as in the famous limestone megablocks.

SAN CALOGERO FLYSCH

The oldest unit recognized in this area is a flysch consisting of grey to blackish pyritic shales and siltstones with intercalations of micaceous sandstones and hybrid arenites. This unit is well exposed along the right bank of the Torrente San Calogero. The age of this unit, based on conodonts, is Lowermost middle Permian (Gullo 1993). In the Torrente San Calogero section similar deposits appear as a chaotic clayey mass containing sandstone blocks. The age of the clayey matrix is the same of the flysch deposits on the basis of conodonts (Catalano *et al.* 1991). Scattered small elements of dark grey calcilutites

with circumpacific radiolarians of Early Kungurian age suggest that these deposits have been affected by synsedimentary sliding and reworking (Olistostrome Unit *sensu* Catalano *et al.* 1991).

RUPE DEL PASSO DI BURGIO LIMESTONES

Stratigraphically younger deposits consisting of white to grey ammonoid-bearing calcilutites with intercalations of reworked skeletal calcarenites are found in the Rupe del Passo di Burgio block. A Wordian age of these deposits is supported by the rich fossil association characterized by ammonoids, holoturian sclerites, ostracods, crinoid ossicles, fusulinids and conodonts (Gemmellaro 1887-1899; Müller 1956; Bender &

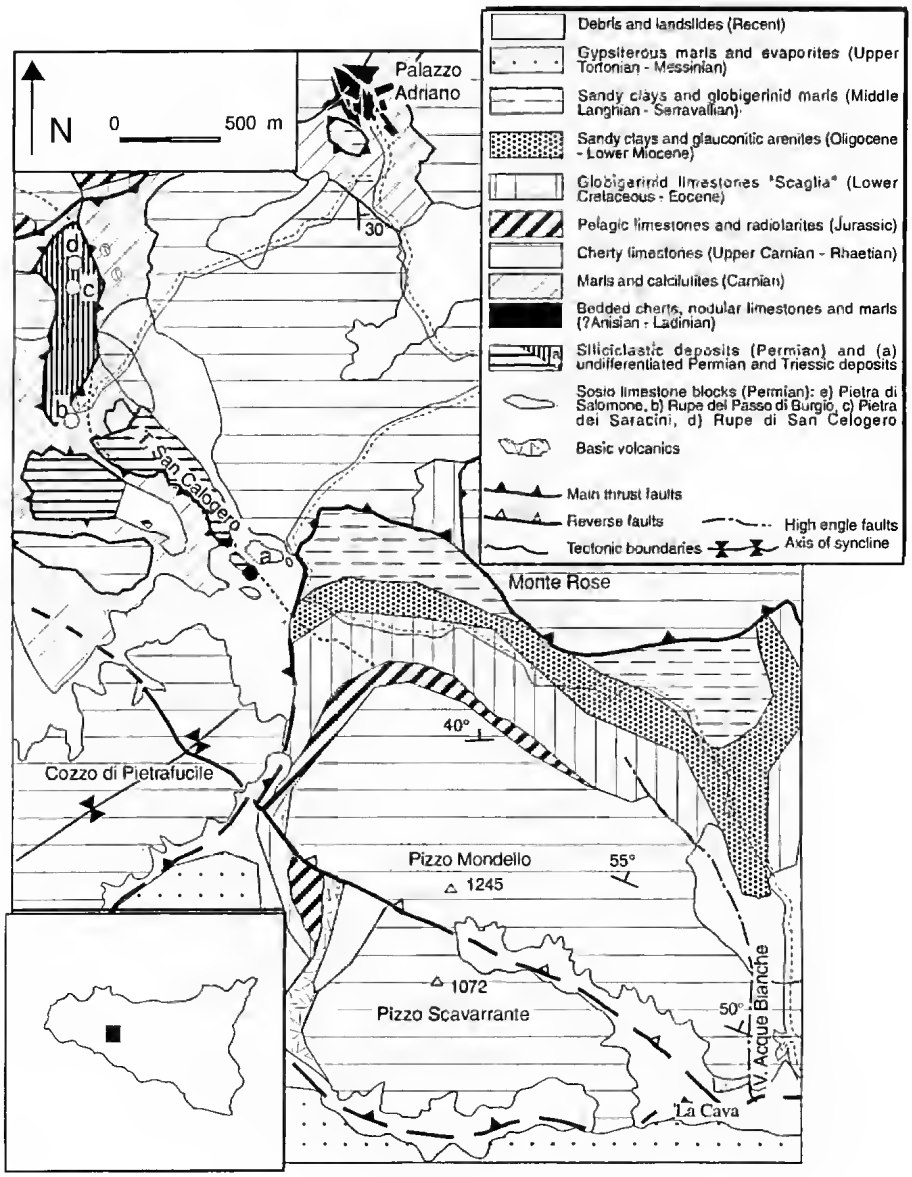

FIG. 3. — Geologic map of the Palazzo Adriano area.

Stoppel 1965; Catalano *et al.* 1991, Kozur 1993a). The Rupe del Passo di Burgio Limestones can be interpreted as hemipelagic carbonates deposited in a distal slope area in which skeletal material, produced in an adjacent platform, was transported downslope by turbidity currents and grain flows. Ammonitic limestones of Wordian age are also described from the Passo di Burgio area, south of the Pietra dei Saracini block (Kozur 1995).

WORDIAN CLAYS

Yellow to grey clays with Wordian conodonts are found in the Sosio Valley in a small outcrop close to the Rupe del Passo di Burgio (Catalano *et al.* 1991).

PIETRA DI SALOMONE LIMESTONES

These deposits characterize the most famous and fossil-rich limestone block outcropping in the Sosio Valley and two smaller blocks present along the Torrente San Calogero valley, known as Pietra dei Saracini and Rupe di San Calogero (Fig. 3). After Gemmellaro's careful descriptions (1887-1899) many paleontological studies were carried out on these limestones, previously regarded as reef limestones (see references in Mascle 1979 and in Flügel *et al.* 1991).

Recent sedimentological and stratigraphic contributions indicate that the Pietra di Salomone Limestones are composed by generally poorly defined thick and, in places, graded beds of coarse calcareous breccias, alternating to skeletal packstone/grainstone beds (Di Stefano 1990; Flügel *et al.* 1991). The latter deposits prevail in the upper part of the Pietra di Salomone block giving rise to a fining-up sequence. The maximum thickness of these deposits is estimated at about 70 m. The breccia elements consist of platform-slope derived carbonates. Reef-derived boundstones/rudstones prevail but also floatstones and grainstones are commonly observed. Sponges, *Tubiphytes*, *Archaeolithoporella*, phylloid algae, richthofenid brachiopods are the main framebuilding organisms, associated to highly-diverse fossil assemblages comprising fusulinids. The age of most of the elements ranges from the Artinskian to the Djulfian. A Late Permian age of the matrix is suggested by fusulinids and conodonts occurring with a large mass of reworked Middle Permian faunas (Flügel *et al.* 1991). The Pietra di Salomone Limestones represent debrite and turbidite sediments deposited in a base-of-slope position. These rocks formed carbonate aprons that could have been accumulated adjacent to or interlayered with the *Red Clay* Unit (see below).

RED CLAY UNIT (Catalano *et al.* 1991)

This is the youngest Permian unit present in the Sosio area, outcropping along the Torrente San Calogero and between the Rupe del Passo di Burgio and the Pietra dei Saracini localities (Gullo & Kozur 1992). It consists of red clays containing fine-grained siliciclastic and carbonate turbidites. A rich pelagic fossil content occurs in the red clays, consisting of circumpacific radiolarians, paleopsychrospheric ostracods and conodonts. It indicates a Late Permian (Djulfian to Changxingian) age (Catalano *et al.* 1991; Gullo & Kozur 1992; Kozur 1993b). The calcareous turbidites mostly consist of skeletal grainstones/packstones with abundant foraminifers (*Reichelina* sp.), *Archaeolithoporella*/*Tubiphytes* fragments and conodonts of Late Permian age (Fig. 3).

PALEOGEOGRAPHIC IMPLICATIONS

Facies associations and ages of the Permian deposits from western Sicily coupled with the palinspastic restoration of the thrust pile forming western Sicily segment of the Apenninic-Maghrebian chain, are consistent with the existence of a wide and persistent deep-water basin along the Africa margin since, at least, the Early Permian time (Catalano *et al.* 1989, 1991; Di Stefano 1990, Bernoulli *et al.* 1990; Robertson *et al.* 1991, Blendinger *et al.* 1992; Kozur 1993b; Vai 1994). Siliciclastic turbidites, associated with carbonate turbidites and debrites formed the sedimentary fill of this basin during the Permian. Shallow-water skeletal material and platform-slope carbonates of well-dated Early, Middle and Late Permian ages were almost continuously transported downslope into the basin, indicating the existence of a mixed terrigenous/carbonate

Western Sicily

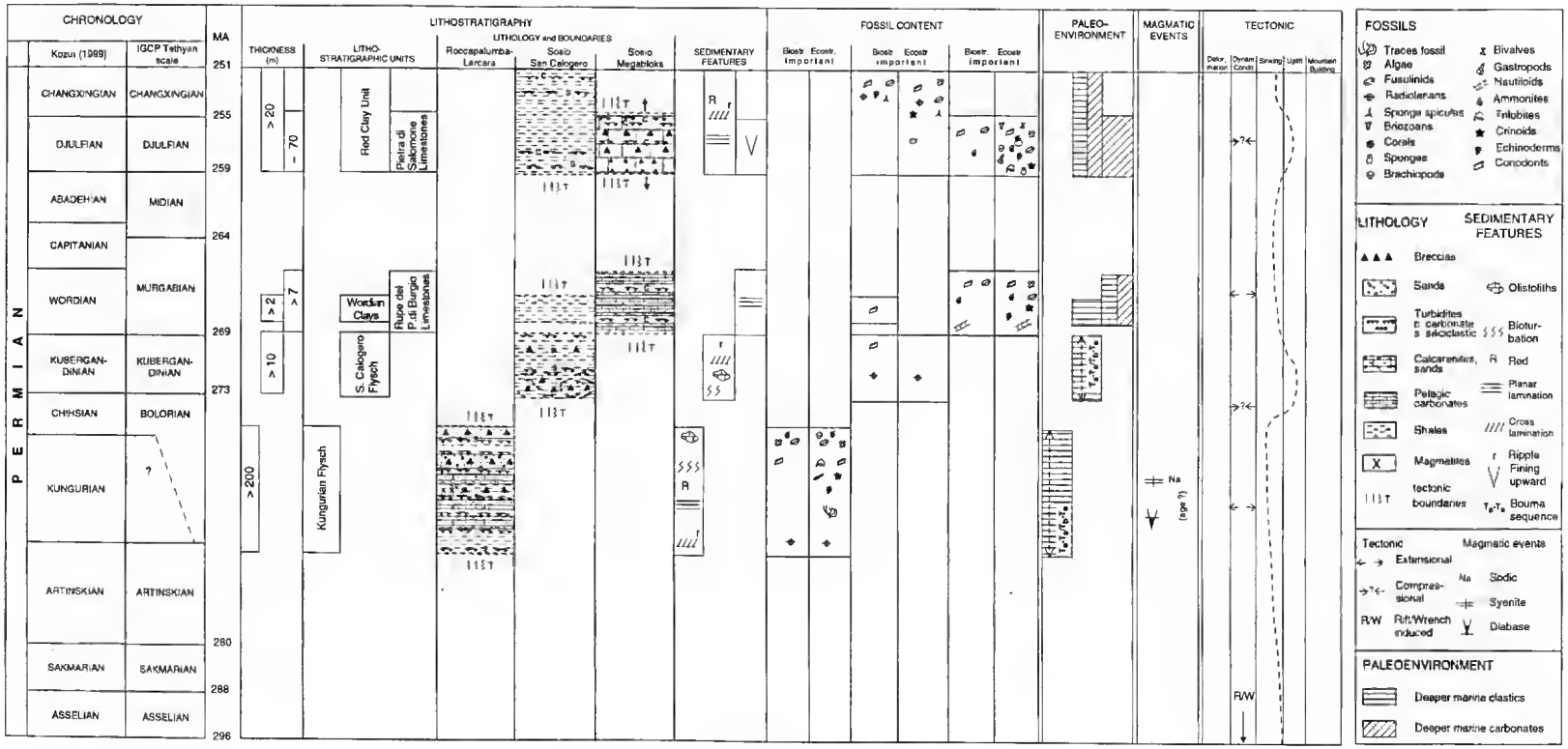

FIG. 4. — Permian lithostratigraphic units of Sicily.

shelf area at the margins of this basin. Part of the clastic carbonates could also have derived from seamount areas inside the basin.

As assumed by Catalano *et al.* (1991), the occurrence of circumpacific deep-water faunas in the Permian deposits of western Sicily suggests a connection of the basin to the Permian Tethys. The most reliable eastward connection of this basin with the oceanic Terhys was through the present-day Ionian basin. This implies a separation of the Adria block from the Gondwanian margin already in the Permian (Vai 1994). Remnants of this basin toward the east are found in Crete (Krahl *et al.* 1986; Kozur & Krahl 1987), Kurdistan (Vasicek & Kullmann 1988) and Oman (Blendinger 1988; Blendinger *et al.* 1992).

The southern edge of the Permian basin of Sicily was represented by the siliciclastic-carbonate platform of Tunisia. Here Middle and Upper Permian deposits, with an upward regressive trend, are well known, reaching a thickness of 6000 m. Facies distribution shows a transition from a reef complex belt to deep-water shaly facies towards the North (Toomey 1991). Remnants of the northern shelf area of the Permian basin of Sicily could be represented by the reworked fusulinid limestones from the Lagonegro basin of the southern Apennines (Donzelli & Crescenti 1970).

The crustal characters of the Permian basin of Sicily are unknown since in the Sicilian chain the sedimentary covers are regionally detached from their original substrate while oceanic crust is well known in the eastern prosecution of the basin (*e.g.* in Oman, Bèchennec 1988).

The Permian basin could have represented either the southern passive margin of the Permian Tethys or a rifting along the Gondwanian margin connected to the main Tethyan domains (Catalano *et al.* 1989, 1991). Crustal extension along the Gondwanian margin could also have been induced by Late Paleozoic mega-shears between Gondwana and Laurussia (Ricou 1994; Vai 1994). The Permotriassic deep-water deposits of Sicily predate, at the Late Carboniferous-earliest Permian time, the extensional phase affecting the Gondwanian margin since the oldest recognized lithostratigraphic unit is a flysch of Kungurian age and thus older syn-rift deposits must have originally underlain the flysch sequence.

Acknowledgments

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Review on continental Permo-Carboniferous deposits in Italy

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ABSTRACT
The paper presents a short, but up-to-date review of the late Paleozoic to Triassic continental deposits of a large part of Italy. These deposits generally crop out in northern Italy, from the Dolomites to the western Alps, in some central and maritime zones of Tuscany, and, much further south, in Calabria and NE Sicily. Since the tectonics of these regions are highly complex, the stratigraphic schemes drawn up in figures 2, 3 only show the most complete and significant lithological successions. From the results, it is worthy of note that the (late)-postHercynian continental sequences under discussion can generally be divided into two main tectonosedimentary cycles. The lower cycle consists both of alluvial-lacustrine siliciclastic deposits and of calcalkaline acidic-to-intermediate volcanic products. On the whole, this cycle ranges from Late Carboniferous to Late Permian times. In the Alps, the overlying cycles includes the well-known Verrucano-Val Gardena clastics, which are still Permian in age. However, the Apenninic Verrucano is younger, generally pertaining to the Middle Triassic.

KEY WORDS
sedimentary continental deposits,
volcanic products,
plutonic bodies,
(late)-postHercynian
metamorphism,
tectonosedimentary cycles,
Upper Carboniferous,
Permian,
Triassic p.p.,
southern and western Alps,
Tuscany,
"Calabro-Peloritan Arc".

RÉSUMÉ
Ce papier présente un bref résumé, qui est une mise à jour des dépôts continentaux d'Italie du Paléozoïque au Trias. Ces dépôts affleurent généralement en Italie du Nord, des Dolomites aux Alpes occidentales, dans quelques zones centrales et maritimes de Toscane, et plus loin vers le sud, en Calabre et dans le NE de la Sicile. La tectonique de ces zones étant très complexe, les schémas stratigraphiques (Figs 2, 3) ne montrent que les successions lithologiques les plus significatives et les plus complètes. Cependant, dans cette revue, de nombreuses données sur les dépôts du Carbonifère et du Permien concernent les régions voisines. À partir de ces résultats, il est intéressant de noter que les séquences (tardi-) post-hercyniennes peuvent généralement être subdivisées en deux cycles tectonosédimentaires principaux. Le cycle inférieur consiste à la fois en des dépôts alluvio-lacustres silicoclastiques et en produits de volcanisme pour la plupart intermédiaire à acide calco-alcalin. L'ensemble de ce cycle s'étend du Carbonifère supérieur au Permien tardif. Dans les Alpes, le cycle susjacent inclut les dépôts détritiques du Verrucano et de Val Gardena, d'âge encore permien. Le Verrucano apennin, est cependant plus jeune, et appartient généralement au Trias moyen.

MOTS CLÉS
dépôts continentaux,
Paléozoïque supérieur à Trias,
Italie.

After the tectonic-metamorphic events of the Hercynian orogeny, the present north-western part of Italy, which ranges approximately from the eastern Dolomite Alps to southern, coastal Tuscany, together with the "Calabro-Peloritan Arc", represented primarily continental domains, where siliciclastic and/or magmatic deposits developed in various ways, right up to the diachronous Triassic marine transgression.

UPPER CARBONIFEROUS

Well-documented Upper Carboniferous successions, which lie unconformably on the Hercynian crystalline basement, crop out in some sectors of the Italian Alps (Como-Maggiore region, western Liguria) and in the northern Apennines (Mts. Pisani, Jano village), and extend to fairly adjacent regions. They generally mark the beginning of a cycle, where the annexed deposits also include the Permian (Italian I.G.C.P. 203 Group 1986; Cassinis *et al.* 1988).

Southern Alps

The scattered, strip molasse outcrops of Manno and Logone, which lie unconformably on the Hercynian crystalline basement of the South Alpine segment, are rich in fossil plants, and constitute the best-known example of the central sector of this chain. Jongmans (1960) identified *Linopteris neuropteroides*, *Pecopteridium*, *Sigillariaephyllum*, *Cordaites* cf. *borassifolius* in the former locality, near Lugano, and classified the flora as middle or B-C Westphalian; Venzo & Maglia (1947) ascribed the latter deposits of the Alpe Logone to Westphalian C, on the basis of the presence of *Calamites* spp., *Pecopteris plumosa*, *Linopteris neuropteroides*, *Lepidodendron weltheimi*, abundant *Sigillariae* and other plants. Nearby, however (*e.g.* in Bedero, on the eastern side of Lake Maggiore), the presence of scarse Stephanian clastic strata and small anthracite lenses has also been generally recognized.
To the west, in the South Alpine lower crust of the Ivrea Zone, the LP-HT granulitic series, with basic and ultrabasic meta-intrusives, date back to about 300 Ma (*e.g.* Pin & Vielzeuf 1983; Pin 1986).

Western Alps

Within the boundaries of the extensively metamorphic western Alps, and as far as the Ligurian segment, the inner lower Austroalpine domain of the Sesia-Lanzo Zone shows the intrusion of a number of (late)-postHercynian granitoid and mafic-igneous bodies. Possible Carboniferous

and Permian detrital sediments, accompanied by intermediate-to-acidic calcalkaline volcanics, are also recorded in the Dent Blanche nappe, near the Switzerland-Italy border (Ayrton *et al.* 1982). In the Pennine areas, both internal sectors (Mount Rosa, Gran Paradiso, Dora Maira) and external sectors (Briançonnais, Gran S. Bernardo) seem to be widely characterized by Carboniferous and Permian clastic sediments, which are still associated with volcanic rocks. (Late)-postHercynian

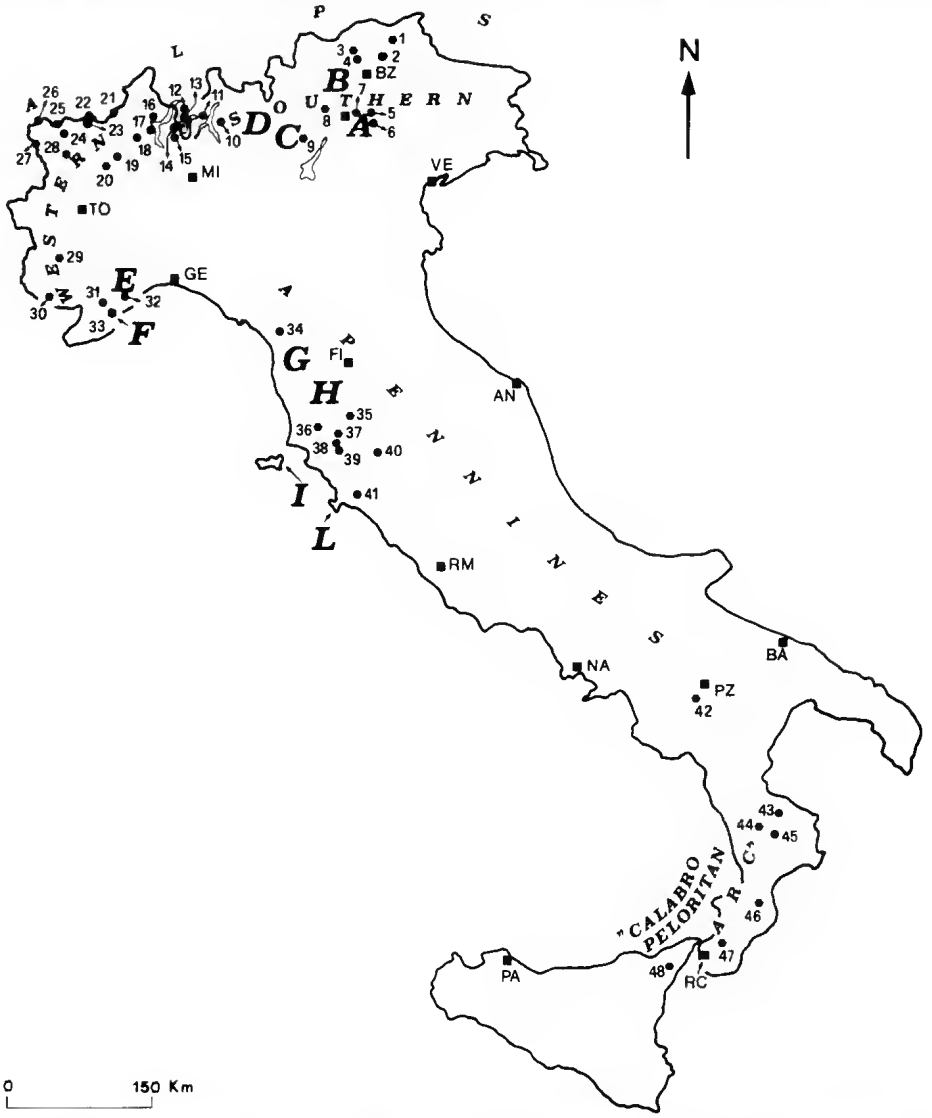


FIG. 1. — Map location. Big letters: stratigraphic sections showed in Figs 2, 3. **A**, Val Fersina Section; **B**, Tregiovo Section; **C**, Val Trompia Section; **D**, Val Seriana Section; **E**, Mallare Section; **F**, Case Tuberto Section; **G**, Mt. Pisani Section; **H**, Iano Section; **I**, Elba Section; **L**, Argentiario Section. Numbers: localities cited in the text. **1**, Rio di Pusteria; **2**, Bressanone; **3**, Mt. Ivigna; **4**, Giogo della Croce; **5**, Cima d'Asta; **6**, Val Sugana area; **7**, Val Fersina area; **8**, Dosso del Sabion; **9**, Basse Giudicarie area; **10**, Val Biandino; **11**, Alpe Logone; **12**, Manno; **13**, Lugano; **14**, Cuasso al Monte; **15**, Varese; **16**, Montorfano; **17**, Baveno; **18**, Roccapietra; **19**, Biella; **20**, Ivrea; **21**, Mt. Rosa; **22**, Matterhorn (Cervino); **23**, Dent Blanche area; **24**, Aosta; **25**, Passo del Gran San Bernardo; **26**, Mt. Bianco; **27**, Passo del Piccolo San Bernardo; **28**, Gran Paradiso; **29**, Dora Maira area; **30**, Cima dell'Argentera; **31**, Ormea; **32**, Mallare; **33**, Case Tuberto; **34**, Alpi Apuane area; **35**, Siena; **36**, Larderello; **37**, Monticiano; **38**, Roccastrada; **39**, Mt. Leoni; **40**, Mt. Amiata; **41**, Mts. Romani; **42**, Mt. Facito; **43**, Longobucco; **44**, Sila area; **45**, Rovale; **46**, Serre area; **47**, Aspromonte area; **48**, Mts. Peloritani area.

intrusives, including granitoids and subordinate gabbro-dioritic bodies, also crop out.

Upper Paleozoic units in the Helvetic (or Dauphinois) Zone *s.l.* of the western Alps occur in the upper Val d'Aosta and in surrounding Swiss and French territory. Huge intrusions (*e.g.* Mt. Bianco granite: 316 Ma, Bussy *et al.* 1989) took place during Carboniferous times. Along the Italian slope of the Argentera massif, a few Westphalian-Stephanian rock-sequences, lying unconformably on the basement, crop out locally. Radiometric age-dating of the Argentera central core granite and other rocks (286-293 Ma, according to Ferrara & Malaroda 1969), which intrude the pre-Westphalian metamorphic complex, is largely in agreement with the age suggested by the afore-mentioned Upper Carboniferous cover.

In the western Ligurian Alps, the Upper Carboniferous is well-known, and again consists of continental metavolcanics and metasediments (Cortesogno *et al.* 1988). In the external Briançonnais (Fig. 2), the (Late)-postHercynian sequence, which rests unconformably upon a pre-Namurian crystalline basement, commences with some detrital deposits and calcalkaline rhyolitic ignimbrites, which are also widespread in the internal sectors. Granitic dikes, and subvolcanic and intrusive granitoid bodies, which are probably connected with this early magmatic phase, occurred at different crustal levels. Later on, fluvial to lacustrine, coarse- to fine-grained, clastic sediments and local graphitic lenses, as well as rhyolitic and andesitic eruptive products, were deposited within fault-bounded basins, which persisted up to Late Permian times. Among these sedimentary units, the Ollano Formation (Fig. 2), at most 1000 m thick, represents the lateral equivalent of the French "Houillère" Zone. Moreover, the ubiquitous andesitic, tuffaceous and lava flow products (Eze Formation), which characterize the Late Paleozoic middle volcanic episode of the Ligurian Briançonnais domain, display a subalkaline potassic series with calcalkaline affinity (Cortesogno *et al.* 1992). A number of fossil plants, identified as *Pecopteris plumosa dentata*, *Sphenopteris schatzlarensis*, *Imparipteris* (*Neuropteris*) *obliqua*, etc. (Bloch 1966), classified the afore-mentioned deposits as upper Westphalian-Stephanian (Cerro *et al.* 1969) and possibly slightly younger Permian (Vanossi 1991).

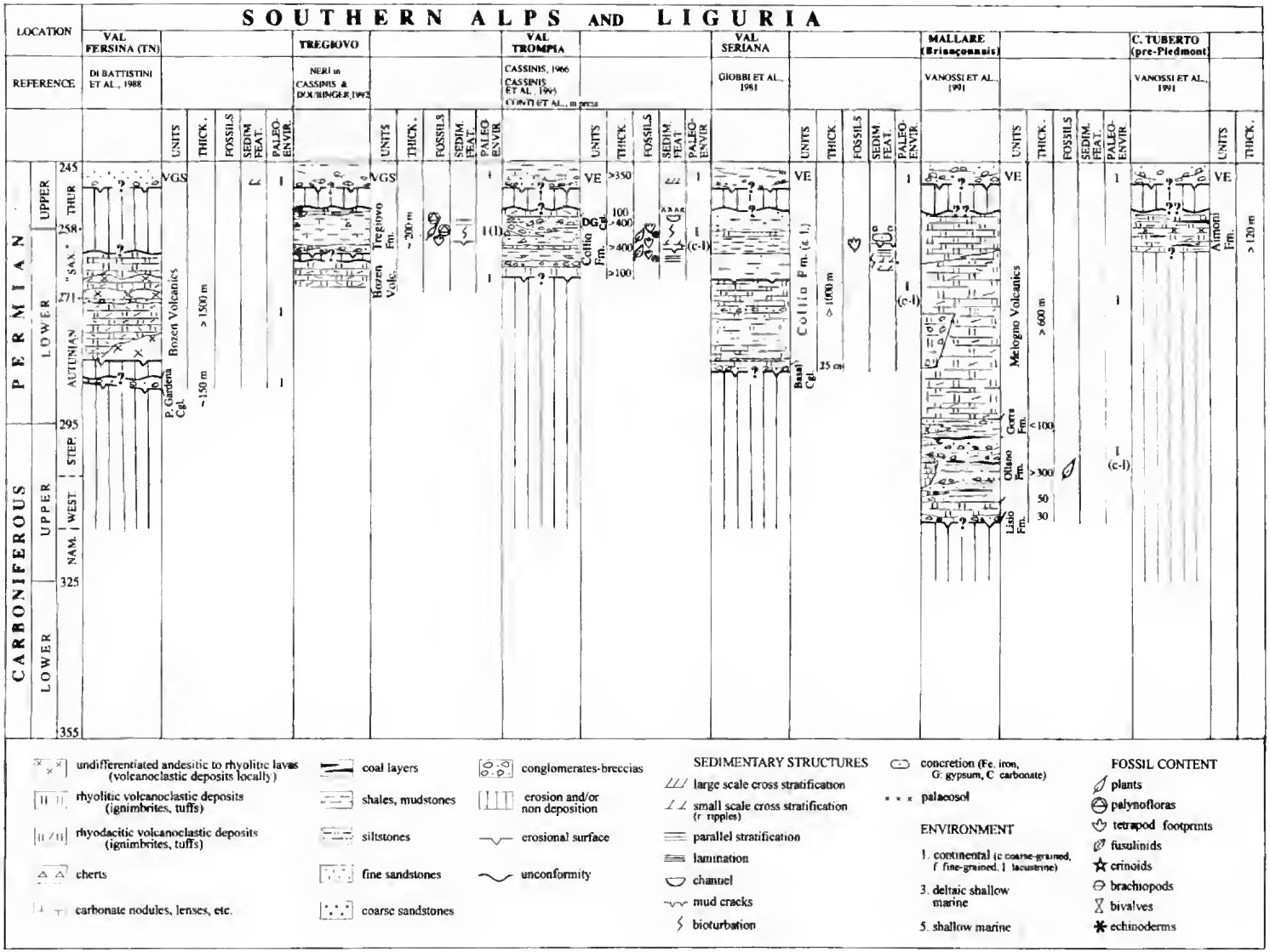
Apennines

In the Apennines, Upper Carboniferous outcrops are well-known in the north-eastern Pisan Mts. and near Jano, south of the Arno River. In the former area (Fig. 3), the San Lorenzo Schists consist of black silty shales, with graphitic layers, which gradually pass, in the uppermost part, to coarse-grained sediments, which can be as much as 300 m thick, and are rich in plant fossils ranging from Wesrphalian D (?) to Early Permian (Remy *in* Rau & Tongiorgi 1974). Pelecypods, ostracods and insects also occur. The crystalline substrate should occur below this unit.

The (Late)-postHercynian, weakly metamorphosed, lower sequence of Jano (Fig. 3), south of Volterra, is essentially made up of alluvial-deltaic sandstone and dark-grey shales, which are a few dozen meters thick, and include plant remains and shallow marine organisms, such as crinoids, pelecypods and possibly brachiopods (Iano Formation). The flora has been identified by Vai & Francavilla (1974) as belonging to the Stephanian A.

Marine influences were also reported for the Island of Elba, where a Permo-Carboniferous, tectonized and slightly metamorphic succession of dark-grey detrital sediments and graphitic levels crops out near Rio Marina, along the eastern coast (Fig. 3). These rocks yield pelecypods, crinoids, echinoids, brachiopods, fusulinids [referred to as *Parafusulina* (Bodechtel 1964; Kahler & Kahler 1969)] and plant remains. Vai (1978) suggested that these fossil-bearing beds range from near the Westphalian-Stephanian boundary to the Early Permian. The unit has been interpreted as a prograding delraic deposit. Further south, the Mt. Calamita Schists perhaps represent a more metamorphic equivalent of the Rio Marina Formation (Vai 1978).

Fig. 2. — Some selected and schematic Upper Carboniferous-Permian continental successions in the Italian Alpine regions (localities in figure 1). Abbreviations: **VGS**, Val Gardena Sandstones; **VE**, Verrucano Lombardo. Vertical distances not time or thickness-related. Geologic time scale from Odin & Odin (1990).


SOUTHERN ALPS AND LIGURIA
LOCATION
REFERENCE
VAL FERSINA (TN)
DI BATTISTINI ET AL., 1988
TREGIOVO
NERI in CASSINIS & DOUBINGER, 1992
VAL TROMPIA
CASSINIS, 1966
CASSINIS ET AL., 1995
CONTI ET AL., in press
VAL SERIANA
GIOBBI ET AL., 1981
MALLARE (Briançonnais)
VANOSSI ET AL., 1991
C. TUBERTO (pre-Piedmont)
VANOSSI ET AL., 1991
UNITS
THICK.
FOSSILS
SEDIM. FEAT.
PALEO-ENVIR.
PERMIAN
CARBONIFEROUS
UPPER
LOWER
THUR
"SAX."
AUTUNIAN
STEP.
WEST.
NAM.
245
258
271
295
325
355
VGS
VE
Bozen Volcanics
P. Gardena Cgl.
> 1500 m
~150 m
Tregiovo Fm.
Bozen Volc.
~ 200 m
Collio Fm.
DG Cgl.
>350
100
>400
>100
Collio Fm. (s. l.)
Basal Cgl.
> 1000 m
25 cm
Melogno Volcanics
Gorra Fm.
Ollano Fm.
Lisio Fm.
> 600 m
<100
>300
50
30
Aimoni Fm.
> 120 m
undifferentiated andesitic to rhyolitic lavas (volcanoclastic deposits locally)
rhyolitic volcanoclastic deposits (ignimbrites, tuffs)
rhyodacitic volcanoclastic deposits (ignimbrites, tuffs)
cherts
carbonate nodules, lenses, etc.
coal layers
shales, mudstones
siltstones
fine sandstones
coarse sandstones
conglomerates-breccias
erosion and/or non deposition
erosional surface
unconformity
SEDIMENTARY STRUCTURES
large scale cross stratification
small scale cross stratification (r ripples)
parallel stratification
lamination
channel
mud cracks
bioturbation
concretion (Fe. iron, G: gypsum, C carbonate)
palaeosol
ENVIRONMENT
1. continental (c coarse-grained, f fine-grained, l lacustrine)
3. deltaic shallow marine
5. shallow marine
FOSSIL CONTENT
plants
palynofloras
tetrapod footprints
fusulinids
crinoids
brachiopods
bivalves
echinoderms

Along the Tuscan Maremma, in the southeastern Argentario promontory, the Triassic Verrucano clastic deposits unconformably overlie weakly metamorphosed grey and black sandstone, which alternates with prevalent, black, carbonate shales (Argentario Sandstones; Fig. 3). Scattered conglomeratic and quartzitic layers also occur. Vai (1978) pointed out the local presence of crinoid remains and suggested a shallow marine environment for these deposits. The age has been tentatively identified by Lazzarotto *et al.* (1964), and by Gasperi & Gelmini (1973), as Late Carboniferous. Further East, in the nearby Romani Mts., prevalent sandy, phyllitic, monotonous rocks, generally referred to as Carboniferous and/or Permian, crop out again beneath the Verrucano *s.l.* (Cocozza *et al.* 1974; Gasperi & Gelmini 1975; Azzaro *et al.* 1976). However, according to Meccheri (*in* Conti *et al.* 1991), these rocks were probably affected by the Hercynian Sudetian phase.

Widespread and thick Paleozoic sequences are also present in several deep wells in the geothermal fields of central-southern Tuscany. In the Larderello area, Elter & Pandeli (1990) related a series of dark, grey-black phyllites, with quartzitic intercalations, to the Upper Carboniferous deposits present elsewhere in the region ("San Lorenzo Group" *in* Bagnoli *et al.* 1979). Southeast of Mount Amiata, in the Piancastagnaio area, the Triassic Verrucano overlies 2000 m of graphite-rich phyllites, metasandstone and metagraywackes (formation A, Elter & Pandeli 1991), which locally yield crinoids, brachiopods, calcareous algae and other fossil remains. They may be correlated to the turbiditic Farma Formation of the Monticiano-Roccastrada massif, which was identified by Cocozza *et al.* (1987) as late Bashkirian-Moscovian in age.

In light of the above, the Late Carboniferous picture of the Apennine continental domains shows no evidence of intense magmatic activity. By contrast, this activity was consistently present in the Alps and the "Calabro-Peloritan Arc". Moreover, it is worth mentioning that in southern Calabria, as in the Ivrea Zone, mafic-igneous, basic bodies occurred, around 300 Ma, during a granulite-facies metamorphism.

PERMIAN

The Permian System of the continental domains under discussion may be, for the most part, divided into two groups or cycles. The lower cycle, which is connected with the previous one of Late Carboniferous age, consists of prevalent detritic and volcanic deposits, whereas the upper cycle generally includes the Verrucano-Val Gardena red clastics. However, the Apenninic Verrucano pertains to Triassic times. Moreover, a marked unconformity, which is associated with a gap of uncertain duration, separates the lower group from the stratigraphic cover.

SOUTHERN ALPS

In the South Alpine region, the lower group is made up of calcalkaline, intermediate and acidic volcanics which alternate, in some strike-slip or pull-apart basins (Cassinis & Perotti 1994), with alluvial and lacustrine siliciclastic deposits. Intrusive, largely calcalkaline granitoid rocks, which are concentrated in the area west of Lake Maggiore and along and near important tectonic lines (*e.g.* the Giudicarie, Pusteria and Valsugana lines), are also attributed to the same igneous activity. From west to east, the Biella-Valsessera, Alzo-Roccapietra, Mottarone-Baveno, Montorfano, Cuasso al Monte, Val Biandino, Mt. Sabion, Mt. Croce, Ivigna, Bressanone and Cima d'Asta plutonic masses represent the best-known examples, and generally have an intrusion age of around 275 Ma. Moreover, in the western South Alpine sector, it is worth noting that calcalkaline mafic-to-intermediate bodies intruded before, during and after the granite batholith emplacement of the so-called "Serie dei Laghi", which is tectonically juxtaposed to the lower crustal Ivrea-Verbano Zone (Giobbi Origoni *et al.* 1988). Among these bodies, an appinitic suite predates the uplift and erosion of the Hercynian belt and the intrusion of the granite plutons (Boriani *et al.* 1988).

In the Bolzano-Trento and Varese-Lugano areas, the igneous, extrusive cover is generally represented by voluminous sequences of up to 1500-2000 m in thickness. On the basis of an idealized stratigraphic succession (Di Battistini *et al.* 1988), the Bolzano-Trento southern plateau is divided from base to top into:

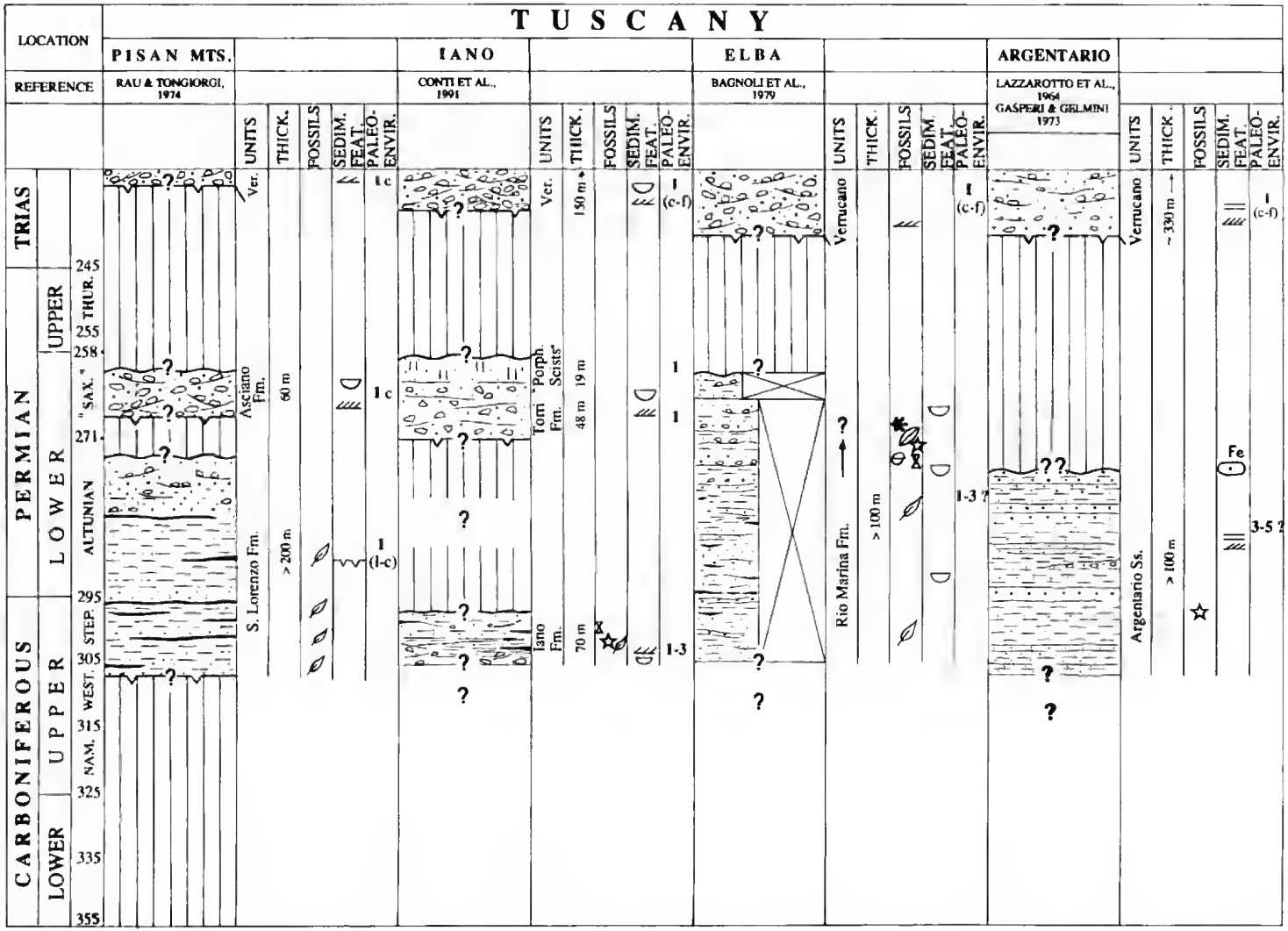


FIG. 3. — Some selected and schematic Upper Carboniferous-Permian stratigraphic successions in the Tuscan areas. Localities and legend in figures 1, 2 respectively. Vertical distances not time or thickness-related. Geologic time scale from Odin & Odin (1990).

1. A "Lower Group" composed of (basaltic) andesitic lavas, trachyrhyolitic lavas, rhyodacitic ignimbrites, dacitic-rhyodacitic lavas and, again, andesitic lavas.
2. A more homogeneous "Upper Group" comprising rhyodacitic ignimbrites, dacitic-rhyolitic lavas, and rhyolitic ignimbrites (Fig. 2).
Early Permian volcanism is indicated by Rb-Sr biotite isochron, which ranges from 276 ± 2 Ma to 267 ± 2 Ma (Barth *et al.* 1993), and by congruent biotite model ages estimated from rhyodacitic ignimbrites in the Lower and Upper Groups (D'Amico & Del Moro 1988), and rhyolitic ignimbrites in the Upper Group (D'Amico *et al.* 1980).
The igneous, effusive, calcalkaline succession of the Ganna area, near Varese, is made up, from base to top, as follows (Bakos *et al.* 1990):
1. Rhyodacitic and rhyolitic tuffs which are intercalated with rhyolitic ignimbrites; the upper part consists of alternating layers of clastics;
2. Clastic and syn-volcanic epiclastic rocks (mainly composed of occasionally thick pyroxene-biotite bearing, andesitic to dacitic lava flows) with overlying rhyodacitic tuffs and rhyolitic ignimbrites with tuffs;
3. Tuffs, ignimbrites and lavas of rhyolitic to rhyodacitic composition.
In the Varese-Lugano area, the top of the aforementioned leucogranitic Cuasso al Monte or Ganna stock intrudes into this section. Hunziker & Zingg (1980) suggested, on the basis of available Rb-Sr whole-rock isotope data on some rhyolitic volcanites of the Val Sesia and Lugano region, that the volcanic activity occurred some 278 ± 3 Ma ago. Moreover, Stille & Bulletti (1987) pointed out that the best age estimate of the Lugano volcanites is given by a Rb-Sr mineral isochron of 262 ± 1 Ma
Generally speaking, the hypothesis of an Early Permian and, in some places, a Latest Carboniferous interval for this post-orogenic volcanism, agrees fairly well with the available paleontological data coming from the intervening sedimentary basins, *i.e.* the well-known fossiliferous Orobic, Collio and Tregiovo fault-bounded basins of the central South Alpine (Fig. 2). However, the macro and microfloral assemblages of the typical Collio and Tregiovo beds, especially the ones pertaining to the latter unit, generally enable us to attribute them to late Early Permian and early Late Permian times (see the Remys and Doubinger *in* Cassinis *et al.* 1995; Fig. 2). In particular, the palynomorphs recognized in the Tregiovo Formation, which include *Lueckisporites virkkiae*, *Corisaccites alutas*, *Crucisaccites varisulcatus*, *Paravesicaspora splendens* and other forms, would seem to indicate the presence of Upper Permian, including the Kazanian deposits. Therefore, the overlying, calcalkaline, rhyolitic ignimbrites appear to testify that the volcanic activity of this area (and probably of a vast part of the South Alpine segment) ended during younger Permian times, before the deposition of the pre-Triassic Verrucano Lombardo and of the more or less coeval Val Gardena Sandstone. Within a general stratigraphic framework, the more recent investigations on the tetrapod footprints found in these basins (Ceoloni *et al.* 1987; Conti *et al.* in press) also concord with this dating.
Therefore, in the South-Alpine segment, the Verrucano-Val Gardena redbeds, which unconformably overlie the above-mentioned deposits and step down onto the Hercynian basement, pertain to the Upper Permian younger cycle. This clastic lithosome is generally missing from Lake Como to the western extremity of the chain.

Western Alps

Along the western Alps, the Hercynian basement of the lower Austroalpine domain underwent a Permo-Carboniferous HT-LP metamorphism that was due to a geothermal anomaly, which in turn was caused by the asthenoshere upwelling and gave rise to granulitic facies. This substrate includes gabbros and granitoids, whose ages are not always well defined, which crop out in the Dent Blanche (Matterhorn gabbro, *c.*250 Ma; Dal Piaz *et al.* 1977) and other nearby smaller klippens. Sediments and volcanics below the Upper Permian Verrucano clastics, as well as (late)-postHercynian granitoids, have also been indicated in some Pennine areas of the chain.
In the Ligurian Alps, the present pre-Piedmont Zone (Fig. 2) is locally characterized by the Lower Permian, meta-volcaniclastic Aimoni Formation of the Melogno "porphyroid" Group,

which is unconformably capped by the younger pre-Triassic Verrucano. At the same time, the Briançonnais area (Fig. 2) was affected by widespread, thick, calcalkaline, rhyolitic and subordinate rhyodacitic ignimbrites, together with pyroclastics (the so-called afore-mentioned Melogno porphyroids); in the uppermost part, however, Cabella *et al.* (1988) found evidence of the onset of a sub-alkaline potassic composition in the Ormea area. In the Helvetic (Dauphinois-Provençal) Zone of the Argentera massif, the Permian continental deposits are extensively developed, with a thickness of almost 2000 m on the French slope.

In the western Alpine domain, the above-mentioned deposits of the lower cycle are unconformably overlain by the Verrucano clastics of the Upper Permian cycle.

APENNINES

According to Bagnoli *et al.* (1979), Permian volcanism probably occurred in the western Apuane Mts. of Tuscany, as indicated by rhyolitic clasts in the basal part of the Middle Triassic Verrucano. This magmatic activity is also supported by the presence of some granitic blocks (308 ± 10 Ma to 287 ± 10 Ma, Eberhardt *et al.* 1962) inside the Ligurian allochthonous structural units. These units have been interpreted as crustal fragments, partially derived from the Tuscan continental margin (Elter *et al.* 1966).

Further south, in some areas of the Pisan Mts., there are red breccias and conglomerates, the so-called Asciano Formation, which are up to 80 m thick and of undefined age. These clastics, interpreted as scarp-foot alluvial deposits (Rau & Tongiorgi 1974), lie either on the San Lorenzo Formation or directly on the Hercynian metamorphic basement (Fig. 3). The presence of red, rhyolitic clasts in the overlying, basal Verrucano, a feature not previously observed in the Asciano Formation, suggests that volcanism was probably active during Permian times, after the Asciano was deposited, but before the Middle Triassic Verrucano.

South of the Arno River (Fig. 3), massive polygenic detrital deposits (Torri Formation) and porphyric products (partly interpreted as acidic volcanics) overlie the Iano Formation. Although the dating of both units is uncertain, it is likely that the porphyric products are Permian. The Triassic Verrucano crops out unconformably above this section, with intermediate, purple, carbonate-bearing siltstones occurring locally.

In the Larderello geothermal area, the presence of clastic units, such as the Mts. Pisani Asciano Fm. and the redbeds (including clasts of acidic volcanics) of the so-called Castelnuovo Sandstone, which resembles the Val Gardena Fm. of the Dolomite Alps, seems to indicate a wider Permian continental domain. Moreover, in the Mount Amiata geothermal field, below the Triassic Verrucano, wells reveal a Paleozoic, metamorphic and tectonised clastic sequence, where a carbonate level with Late Permian fusulinids, such as *Praeparafusulina* cf. *lutigini*, *Polydiexodina* (*Eopolydiexodina?*) cf. *shabalkini*, *Cancellina* sp., *Parafusulina* sp., *Pseudofusulina* sp., etc., occurs at the transition between the so-called formations A e C (Elter & Pandeli 1991). According to Pasini (1991), the whole association indicates the *Cancellina* Zone (Kubergandian); in addition, the presence of *Praeparafusulina* links this finding to that of Bodechtel (1964) in the Island of Elba, and also to the Artinskian of the Southern Alps. Thus, from the above it may be hypothesized that a great part of formation C (about 700 m drilled) is Permian in age (Conti *et al.* 1991).

On the Island of Elba (Fig. 3), the upper part of the Rio Marina Formation, which includes alluvial-deltaic and marine sediments with *Parafusulina* sp., belongs to the Early Permian. Continental, clastic deposits, beneath the Triassic Verrucano, have also been attributed, at least partially, to the same age in the Argentario and Romani Mts. (Fig. 3).

Farther east, in southern Tuscany, between the Montagnola Senese and Mt. Leoni, the Upper Paleozoic sequence is essentially characterized by the presence of marine conditions.

In the southern Apennines (Basilicata), mainly Upper Permian (Murgabian-Dzhulfian *s.l.*) carbonate clastics occur in the lower part of the Triassic Mt. Facito Formation. A continental regime at the end of the Permian (Dorashamian) may be presumed, as we have no data to prove otherwise.

The "Calabro-Peloritan Arc", which is the result of at least six different composite microplates of a former Hercynian basement (Vai 1991), reintroduces continental domains. The metamorphic substrate was generally intruded by granitoids; however, a Permo-Carboniferous cover is lacking or unknown. In the Longobucco structural block, granodiorites and younger Al_2SiO_5 - bearing granites, of 284 ± 14 Ma (Wieland 1978) occurred before the deposition of Verrucano-type red clastics, referred to by Baudelot *et al.* (1988) as the top of the Triassic. To the south, near Rovale, gabbroic and dioritic bodies with Rb-Sr biotite cooling ages of 270-280 Ma (Caggianelli *et al.* 1991), as well as other close granodioritic rocks, are cut by porphyritic granitic dikes and plugs. According to Campana *et al.* (1991), in the Serre-Capo Vaticano areas, the radiometric age-datings of calcalkaline granitoids, which range from tonalites to granodiorites-monzogranites, with minor quartz diorites/gabbros, have been estimated as approximately 270-291 Ma. In the Aspromonte block, the time-span of some peraluminous intrusions within the Hercynian metamorphic basement ranges between 282 and 286 Ma (*in* Spalletta & Vai 1990).

In the above-cited areas, the sediments related to the Verrucano belong to the Triassic. The Tuscan deposits lie unconformably on those of the lower cycle, or step down directly over the Hercynian metamorphic substrate, and are generally ascribed to Mid-Triassic times. Although the Apenninic Verrucano is not generally as young as the Carnian, recent dating of the Longobucco and Longi Verrucanoes in the "Calabro-Peloritan Arc" as latest Triassic (Baudelot *et al.* 1988) places an outside limit on the diachronism of the deposit.

Sicily

In north-east Sicily, the Mts. Peloritani block includes some granitoids, which date from 293 ± 9 Ma, and are situated within a strongly deformed crystalline substrate and below a Triassic Verrucano-like clastic unit (*in* Spalletta & Vai 1990). As in Basilicata, the western sector of the island displays highly fossiliferous Permian marine deposits, the basement of which is unknown.

GENERAL REMARKS

In the record of continental domains in Italy from Carboniferous through to Triassic we can recognize several sedimentary and/or tectonic cycles as well as other events.

In some Alpine regions a first main cycle began in the Late Carboniferous, where it is documented by the Westphalian-Stephanian deposits of the Como-Maggiore area, of the western Liguria (Viozene) and of other localities. This cycle continued, in a seemingly more widespread fashion, into various levels of the Permian, up to the onset of the so-called Verrucano rock-units, which belong to the upper part of this System.

In some places of the central South Alpine sector, as in the Collio and Tregiovo basins, the macro- and microfloras present generally enable us to attribute the above cycle to the late Early Permian and, in particular regarding the Tregiovo beds, also to slightly younger Late Permian times. However, as the Permo-Carboniferous sedimentary and volcanic succession of the Alpine region is subjected to consistent and rapid geometric changes, it is problematic and often impossible to achieve extensive correlations of the local data. Further difficulties arise owing to the presence of stratigraphic discontinuities. These unconformities are not only confined to the boundaries of this lower cycle but also occur inside its vertical and lateral development, and mark the presence of gaps of various but as yet unknown time-duration.

As indicated earlier, in the Alpine continental areas, the Verrucanoes and, to the east, the more or less coeval Val Gardena Sandstones (together with some underlying conglomeratic units, such as the Daone Cgl. in the Giudicarie area) mark the beginning of another Permian upper cycle. Palaeontologic data (plants, palynomorphs, tetrapod footprints) and the stratigraphic position of the Val Gardena redbeds, which pass laterally and vertically to the Upper Permian shallow-marine Bellerophon Formation, generally ascribe the above units to Late Permian. The overlying Lower Triassic Werfen Formation and its lateral equivalents unquestionably confirm this attribution.

In the Tuscan Apennines, the stratigraphic

schemes and other data in the text indicate the persistence of the aforementioned older cycle. However, as in Iano and Elba, the continental deposits show some Late Carboniferous to Early Permian shallow-marine intercalations, which testify to a former irregular landscape of the region. Moreover, the Upper Permian cycle has not, as yet, been recorded in this area. According to the stratigraphic successions of figure 3, the Verrucano deposits essentially developed during Middle Triassic times. As a consequence, the presence at Pta Bianca, near La Spezia, of prevalent Anisian and Ladinian marine deposits (Martini *et al.* 1986; Passeri 1988), which rest unconformably over the Hercynian crystalline basement, leads us to relate the overlying Appenninic Verrucano to a cycle evolution which does not coincide with that of the Alpine region.

In figures 2, 3, the contact between the two indicated cycles or groups deals with tectonic, paleogeographic and probably paleoclimatic variations. Structural highs and lows during the older cycle were formed in the context of a prevalent tectonic transcurrent regime (see Arthaud & Matte 1975; Vai *et al.* 1984; Ziegler 1984; Massari 1988; Rau 1990; Cassinis & Perotti 1994; and others) which, during the younger cycle, changed into a more pronounced extensional framework. Moreover, in the South Alpine area the second cycle led to a complete extinction of the (late)-postHercynian volcanic activity.

Erosion during the formation of the Verrucano and Val Gardena deposits generally caused progressive flattening of the landscape, and this ultimately favoured a decisive transgression of the sea. However, the shallow-marine intercalations in some Stephano-Autunian rocks (Iano, Elba) of the northern Apennines demonstrate the relative proximity of this sea from Latest Carboniferous-Early Permian times, and indicate a general provenance from the east. These incursions reached north to the Carnic Alps, where the post-Westphalian succession of the lower cycle was persistently characterized by marine conditions.

South of Tuscany, the particular geological scenario of the "Calabro-Peloritan Arc", which is rich in the pre-Triassic plutonics but lacks a mid-Carboniferous-Permian sedimentary cover, probably derived from a group of lands in front of the Corsica-Sardinia block, but differently situated, and seemingly affected by a mosaic of deeper structural levels that were later exhumed by the Alpine cycle.

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Upper Carboniferous to Lower Permian continental deposits in Sardinia (Italy)

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ABSTRACT
The paper is a brief outline on the sedimentary and volcanic continental successions of a number of Sardinian basins, which have been attributed to Permian and, locally, also to Late Carboniferous times. In general this (late)-postHercynian picture is similar, in most aspects, to the situation in nearby Corsica, and is also reminescent of conditions in South France and Spain, with which Sardinia and Corsica were linked before beginning their drift toward the Tyrrhenian.

KEY WORDS
continental basins,
sedimentary deposits,
igneous products,
Upper Carboniferous,
Lower Permian,
Sardinia.

RÉSUMÉ
Cette note est un aperçu des successions sédimentaires et de volcanisme continental dans les bassins de Sardaigne qui ont été attribués au Permien et, localement, au Carbonifère supérieur. En général, cette photographie du (tardi)-posthercynien est similaire dans la plupart de ses aspects à la situation de la Corse voisine et évoque aussi ce que l'on connaît en France méridionale et en Espagne, avec lesquelles la Sardaigne et la Corse étaient liées avant leur séparation vers la Tyrrhénienne.

MOTS CLÉS
bassins continentaux,
dépôts sédimentaires,
produits ignés,
Carbonifère supérieur,
Permien inférieur,
Sardaigne.

After the Hercynian orogeny, during Late Carboniferous and Early Permian times, a large-scale calcalkaline magmatism took place on the island (Fig. 1). The intrusive sequence gave rise to hundreds of plutons over a period of more than 25 Ma, from at least 310 Ma to about 280 Ma This plutonic complex forms the southern part (about 6000 km^2) of the Sardinian-Corsican batholith, which, in Sardinia, largely comprises tonalites to tonalitic granodiorites and younger monzogranitic granodiorites to leuco-monzogranites. Post-tectonic plutons, which occurred under a tensional regime after rapid regional uplift, contain leucogranites (Ghezzo & Orsini 1982; Carmignani *et al.* 1989).

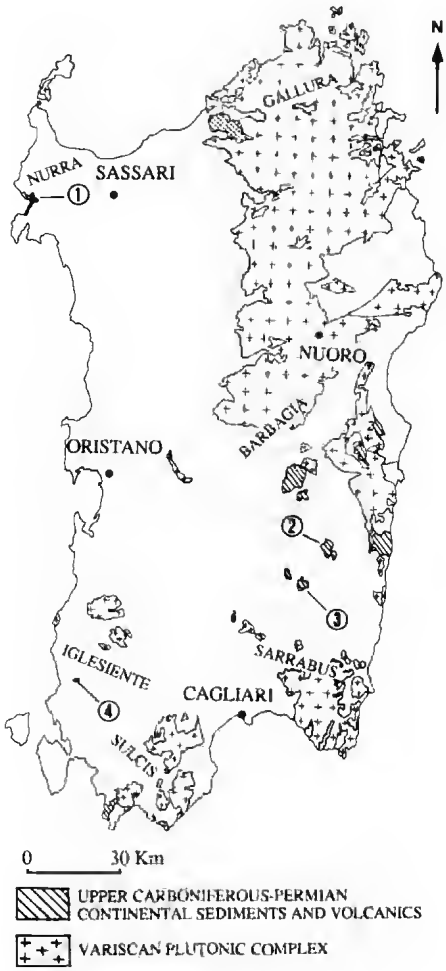

FIG.1. — Location map of the stratigraphic columns drawn up in Fig. 2. **1**, Pta Lu Caparoni; **2**, Perdasdefogu; **3**, Escalaplano; **4**, San Giorgio.

The (late)-postHercynian terrigenous and volcanic sequence lies unconformably on a heterogeneous, generally tectonized metamorphic basement. As in many parts of Permo-Carboniferous continental Europe, it is made up both of fluvial to lacustrine clastic deposits, which accumulated within more or less subsiding fault-bounded basins, and of wider volcanic products, which are generally acidic to intermediate in composition.

At present, the San Giorgio Basin in Iglesiente (SW Sardinia) appears to be the oldest Upper Palaeozoic sedimentary outcrop on the island (Fig. 2). Its upper detrital deposits, on the basis of fossil macroflora with *Pecopteris*, *Calamites*, *Neuropteris*, *Cordaites*, etc. (Cocozza 1967), and of palynoflora which yields *Calamospora pallida*, *Florinites parvus*, etc. (Del Rio 1973), have been identified as belonging to the Upper Stephanian. More recently, however, in the lowermost layers, the discovery of tetrapod footprints, which have been referred to the genus *Salichnium* (already recorded from the Westphalian of Central Europe and North Africa) and thus attributed to microsaurs, has encouraged the hypothesis that the sedimentation may have begun in the San Giorgio Basin in former times (Fondi 1980).

On the other hand, during the Early Permian, a certain number of well-developed basins (Mt. Lu Caparoni in Nurra, Seui-Senlo in Barbagia, Perdasdefogu in Ogliastra, Escalaplano in Gerrei, Lake Mulargia in Sarcidano, Guardia Pisano in Sulcis) occurred on the island. They were characterized by the above-mentioned (late)-postHercynian succession (Fig. 2), during which volcanic products (tuffs, ignimbrites, lavas and other igneous extrusive aspects) played an important role, and were widespread over external areas. These continental deposits, which range in thickness from a dozen to some hundreds of metres, are normally rich in Autunian plants, such as *Autunia*, *Odontopteris*, *Pecopteris*, *Annularia*, *Ernestodendrion*, *Taeniopteris*, *Sphenopteris*, *Cordaites*, etc. (Novarese 1917; Oosterbaan 1936; Maxia 1938; Comaschi Caria 1959; Pecorini 1962, 1974; Gasperi & Gelmini

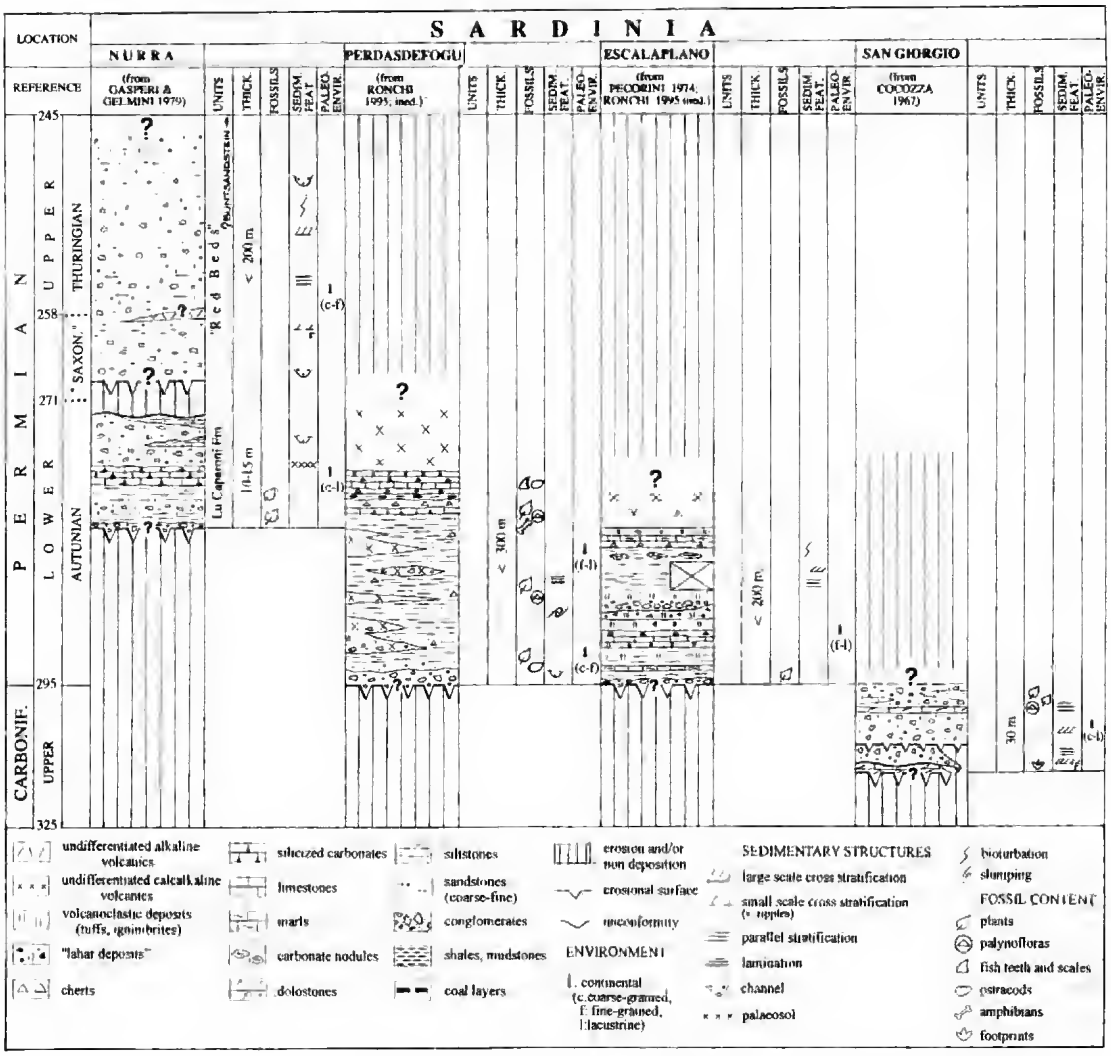

FIG. 2. — Some Upper Palaeozoic sedimentary and volcanic successions of Sardinia. Vertical distances not time or thickness-related. Geologic time scale from Odin & Odin (1990).

1980; Francavilla *et al.* 1977; Broutin pers. comm.) and sporomorphs, such as *Potonieisporites novicus*, *P. bharadwaj*, *Latensina trileta*, *Candidispora candida*, *Cordaitina*, *Florinites*, *Limitosporites*, etc, in the Guardia Pisano basin (Barca *et al.* 1992).

The temporal distribution of the overlying permotriassic, coarse- to fine-grained, mainly red, detritic sediments, as in the Mt. Lu Caparoni and Lake Mulargia basins, is not yet clearly defined. The lower boundary of these clastics probably seals a gap of different, but still uncertain magnitude. Moreover the radiometric age-dating from a large number of Permian volcanic rocks (Cozzupoli *et al.* 1971, 1984; Del Moro *et al.* 1974; Lombardi *et al.* 1974; Edel *et al.* 1981) produced unreliable results.

From the above, it follows that the (late)-postHercynian picture in Sardinia is similar, in most aspects, to the situation in nearby Corsica, and is also reminiscent of conditions in Provence (France) and Spain, with which Sardinia and

Corsica were united before beginning their drift toward the Tyrrhenian. The Late Carboniferous to Early Permian fault-block landscape may have been formed during the transcurrent regime, which is thought by many to have characterized the European Late Paleozoic climax. This regime was contemporaneous with the extensional movements linked to the progressive thinning of the Hercynian crust.

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Late Carboniferous to Early Permian palaeogeography of the Italian and central Mediterranean area

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ABSTRACT
An attempt is made at deriving palaeogeographic constraints for late Carboniferous to early Permian restorations from the new stratigraphic data mainly collected in previously poorly known marine deposits of the circum-Mediterranean area. The assumption of an early Permian emplacement of oceanic crust in the eastern Mediterranean Levantine and Ionian Seas is independently supported by the new evidences of deep water facies and faunas from Oman to western Sicily. The bearing on the palaeogeographic reconstruction for the Moscovian and Artinskian time intervals are tentatively suggested by means of two new sketch maps.

KEY WORDS
lithofacies,
palaeobiogeography,
oblique rifting,
oceanic crust,
deep sea deposits,
Tethyan realm.

RÉSUMÉ
Un essai de reconstitution est fondé sur les contraintes paléogéographiques du Carbonifère supérieur au Permien inférieur, à partir de nouvelles données stratigraphiques acquises sur des dépôts, jusque là assez mal connus, du pourtour Méditerranéen. L'hypothèse d'une croûte océanique du Permien inférieur dans la Méditerranée orientale levantine et ionienne est corroborée indépendamment par de nouvelles preuves des faciès profonds et des faunes d'Oman et de Sicile occidentale. Les reconstructions paléogéographiques pour le Moscovien et l'Artinskien sont effectuées à partir de deux nouvelles cartes.

MOTS CLÉS
lithofaciès,
paléobiogéographie,
ouverture oblique,
croûte océanique,
dépôts profonds,
Téthys.

A critical review of surface and subsurface stratigraphic data published from the Italian area (Fig. 1) in the last two decades or so (references in Cassinis, Cassinis & Ronchi, Di Stefano & Gullo, Pasini & Vai, Vai & Venturini, this volume) has changed quite considerably the usual interpretative palaeogeographic scenario of the central and western Mediterranean areas in the late Carboniferous to early Permian time interval dominated by different stages of Pangaea development (Bosellini & Hsü 1973; Smith & Briden 1977; Rau & Tongiorgi 1981; Irving

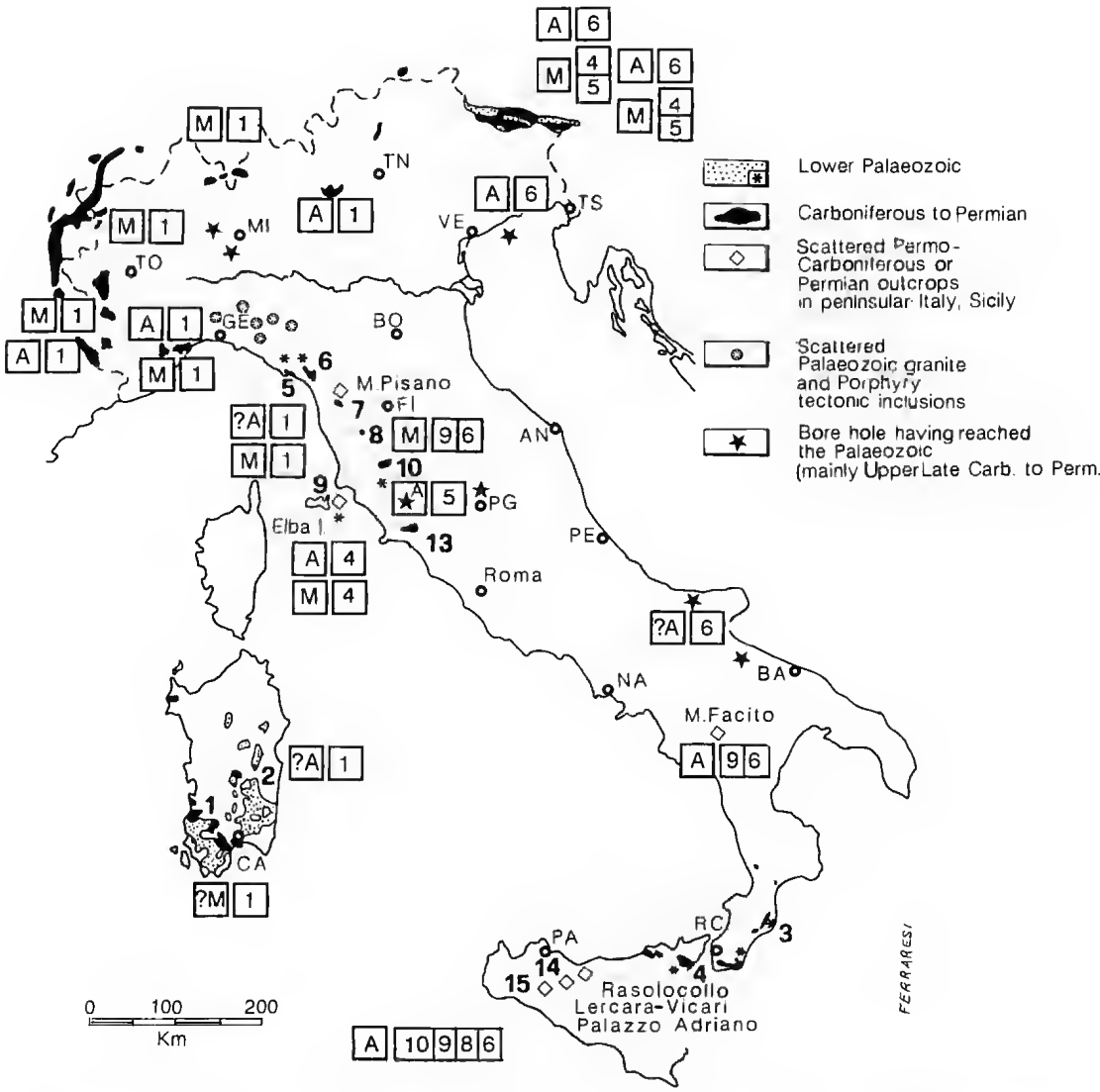

Fig. 1. — Location map of the Palaeozoic rocks in Italy, showing distribution and facies of the Moscovian and Artinskian stages. **M**, Moscovian. **A**, Artinskian. Numbers in boxes relate to legend of figure 3. Numbers in bold refer to stratigraphic sections described by Vai (1978): **1-2**, SW and SE Sardinia; **3-4**, Stilo area and Peloritani Mts., Calabro-Peloritan block; **5**, Punta Bianca, La Spezia; **6**, Apuane Alps; **7**, Pisani Mts.; **8**, Iano; **9**, Elba Island; **10**, Farma area, Monticiano-Roccastrada; **13**, Romani Mts.; **14-15**, Lercara-Roccapalumba and Palazzo Adriano (Sosio), W Sicily. The Verrucano Lombardo, Val Gardena and Bellerophon Formations are not shown.

1982; Sengör *et al.* 1988; Ziegler 1988, 1989). According to Vai (1994), new data from peninsular Italy and especially from western Sicily suggest an alternative scenario. It is based on two critical points: (1) the deep Ionian to Levantine Sea crust is best interpreted as a fossil, thermally contracted, undeformed oceanic crust emplaced following the early Permian (to possibly mid-Triassic) trans-Mediterranean (to Caribbean) oblique rift; (2) the distribution of the benthic marine Tethyan fauna (fusulinids, brachiopods, etc.) requires a sea-way connecting western Tethys to Texas, Bolivia and Colombia during part of the Permian. Recent reviews of the regional Permo-Triassic data from Sicily (Catalano *et al.* 1995; H. Kozur, comm. at the XIII ICC-P, Krakow, 1995) are consistent with the previous scenario.

This short contribution is aimed at providing a tentative palaeogeographic interpretation of the data collected from the Italian area and described in the five previous contributions (this volume). A synopsis of data is presented in figure 1. The meaning of the data in the frame of the Mediterranean is discussed separately following a stratigraphic order.

LATE CARBONIFEROUS: MOSCOVIAN (Fig. 2)

The Moscovian palinspastic picture around the present Mediterranean areas is dominated by an emergent area to the north (main Hercynian Europe) and a marine area to the south. This marine area is separated into an eastern partly oceanic portion and a western shallow epicontinental sea by the north-south trending large peninsula shown as the Africa Promontory merging northward to the Hercynian Europe in the Alps region.

The Italian area proper can be separated palinspastically into four parts:

1. The intra-Hercynian eastern part includes the entire Southern Alps to outer Dinarides segment. From west to east both the Hercynian chain and its post-Hercynian cover show a consistent transition from inner to outer tectono-metamorphic zones and from continental through shallow marine to deeper marine depositional environments. Palaeobiogeographic affinity of benthic animals (fusulinids, corals, brachiopods, trilobites) mainly points out to the Russian Platform, the Urals and middle Asia. Floral elements have western European Eurasian affinity.

2. The extra-Hercynian Panafrican foreland of the African Promontory. It is mainly represented by uplifting basement areas with ongoing erosion and possible thin marine ingression over its middle western part (in the Gargano 1 well area).

3. The intra-Hercynian Tuscan Apennine part. This area, poorly known until recently, is of special interest because it shows an almost continuous marine deposition from early-middle Carboniferous to early Permian in a foredeep-foreland setting (as for the setting of Cantabria and the south Portuguese zone). Again from north to south a transition from inner to outer tectonometamorphic zones appears. Depositional environments, however, range from continental to shallow marine and deeper marine clastics, to shallow marine carbonates and to emergent foreland. Fossil groups such as corals and conodonts show major biogeographic relation with Spain and central American faunas (Ferrari *et al.* 1977), whereas floral elements are typically western European.

4. The intra-Hercynian Sardinia-Calabrides-Kabylides-Betides partis characterized by scattered, thin and poorly developed late Carboniferous to Permian continental deposits with west European floral affinity.

At a more general level, active fronts are found only in the oceanic domain. The continental crust domain is relatively quiet: no first order transcurrent or transform faults appear. The extent of shallow marine deposits outside the Hercynian front and even inside is quite large (and larger than in the Permian). This suggests a low isostatic uplift rate of the orogenic area, consistent with small volumes of deep seated granitoid intrusions. Both land and shallow seas are characterized by a tight network of small-scale pull-apart basins. This time interval is dominated by extension to small-scale transtensional conditions.

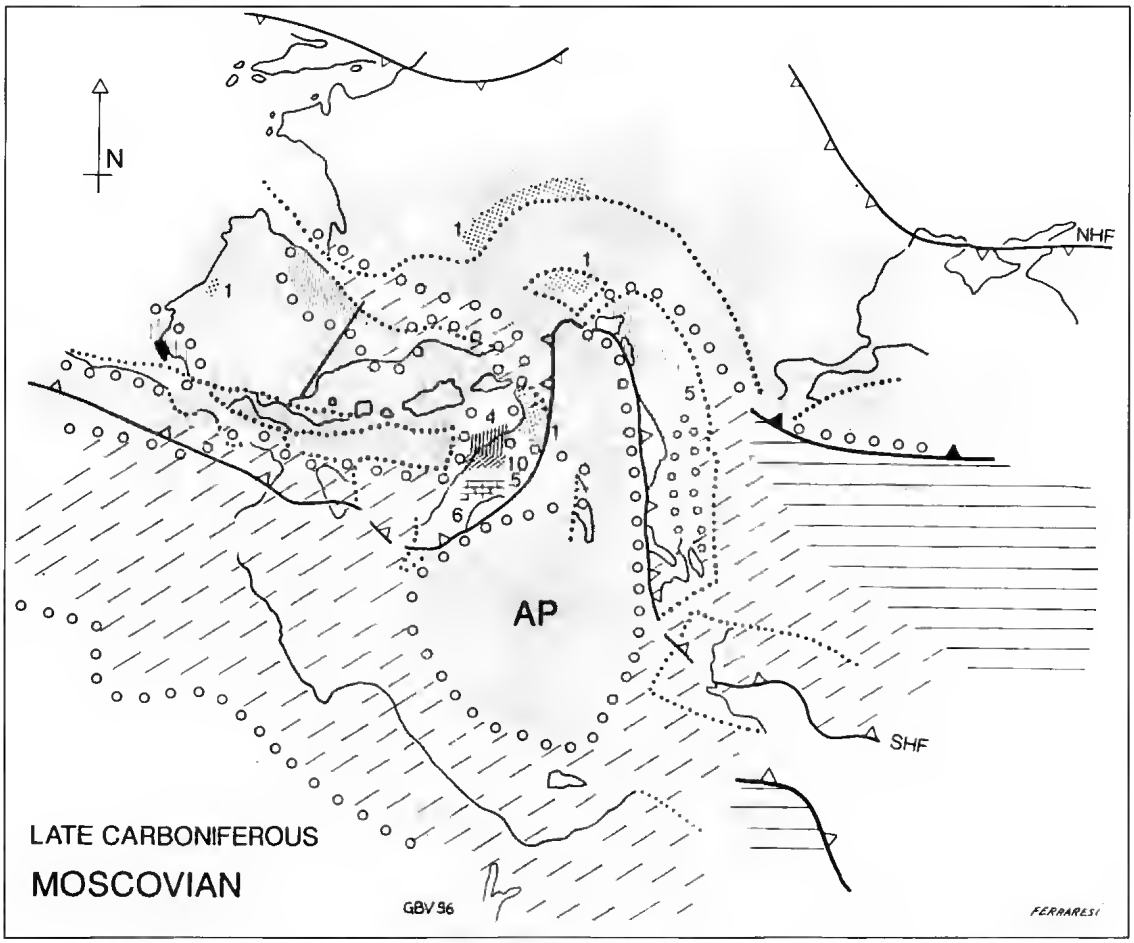

FIG. 2. — Tentative Moscovian palaeogeographic-palaeotectonic map of the circum-Mediterranean area. **AP**, African Promontory during the late Carboniferous. **NHF-SHF**, north and south Hercynian fronts. See figure 3 for legend, and Vai (1994) for further explanations of symbols.

LATE EARLY PERMIAN: ARTINSKIAN (Fig. 3)

Two quite contrasting processes are shown on the map. A prominent regressive trend is documented in northern Africa, from Arabia to large parts of Lybia and Algeria, and in the Cantabrian region (compare figure 3 with figure 2). Relevant trangressive conditions are shown in the rifting Black Sea (Dobrugea) and Iulian-Carnic areas, and even more all through the south Mediterranean region as far as Tunisia.

The former African Promontory becomes kinematically detached from its mother Africa by the westward opening of the Permo-Triassic Tethys, and gives rise to a structurally independent Adria block surrounded by the southern front of Hercynian Europe. The larger southern part of the Adria block becomes submerged by the Artinskian shelf sea. Again, the Italian area can be divided into four parts:

1. The Southern Alps and external Dinarides with depositional environments ranging from continental to shallow marine carbonates to deeper marine clastics passing eastward to the contracting Palaeo-Tethys branch. Both benthic organisms and conodonts suggest Russian to Chinese palaeobiogeographic affinity.

2. The Adria block with mainly erosional continental conditions to the north and shallow marine deposition to the south with important carbonate platforms.
3. The Tuscan, Southern and Sicily Apennine belt (extending westward to the Tunisian Maghrebian chain). It shows transition from continental deposits in northern Tuscany (San Lorenzo Basin, Mt. Pisano) to shallow clastics and carbonates in southern Tuscany (Elba Island, Farma area) to a complete sequence of depositional environments from shallow-water carbonate platform to deep pelagic and turbidite, whose rocks are often reworked as in the tectonically shorthened Mt. Sicani (Sosio valley, and surrounding areas, western Sicily).
4. The Sardinia-Calabrides-Kabylides-Betides belt characterized by erosion or thin continental deposition.

At a more general level, the following facts are relevant.

There is a general major coast line retreat concurrent with the trangressive character of marine deposits in the Mediterranean belt. This is mirrored by the fact that the Permian starts with a transgression followed by regression at a global level and especially in Gondwanaland, whereas an initial regression is followed by transgression in the Hercynian Southern Europe and Northern Africa.
Large volumes of volcanics and epiplutonic granitoids are emplaced concentrating along preferred narrow belts (*e.g.* the Venetian and the Lombardy Lakes-Corsica belts) close to major shear lines.
The already actived large-scale dextral megashear in the Levantine and Ionian Seas is propagating westward, accompanied by additional fragmentation of W Europe and its foreland by means of a conjugate megashear system.
The expanding Permo-Triassic Tethys shifts Cimmeria in such a way as to close the Palaeo-Tethys ocean. Deep marine calcareous to radiola-

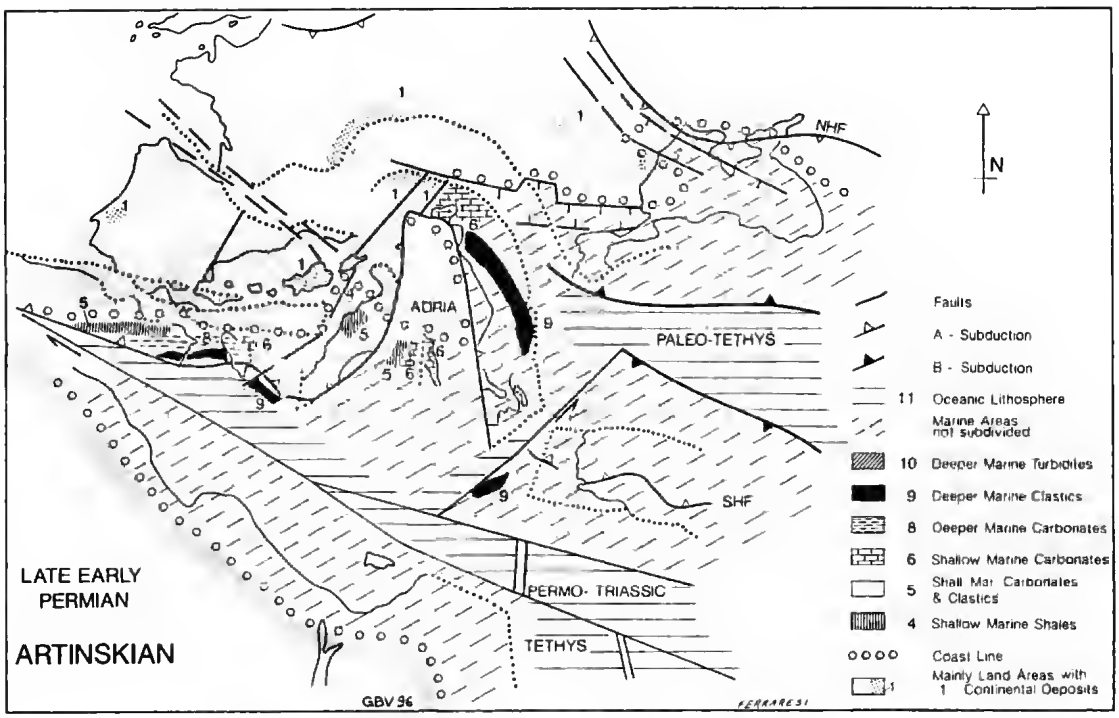

FIG. 3. — Tentative Artinskian palaeogeographic-palaeotectonic map of the circum-Mediterranean area. Notice the intra-Permian crustal separation of Adria from its Precambrian to late Palaeozoic motherland Africa (see figure 2 for symbol explanation).

ritic facies have a climax within the eastern and central Mediterranean area which will be more or less continuing up to the late Triassic especially in the two Permo-Triassic Tethyan edges. In fact, the regionally anomalous marine to deep marine Permo-Triassic or Triassic sequences (or material) of Punta Bianca (N Tuscany), Monte Quoio (S Tuscany) and Lagonegro (Lucania) can be connected only with a south-eastern sea-way. The mid Triassic alkaline volcanics of W Sicily, Punta Bianca, Lagonegro, Budva, Pindos (all associated with deep pelagic rocks) and those similar of the Iblei Mts. in E Sicily (associated with shallow-water carbonate platform) are consistent with this picture. This is further true also for the deep-pelagic calcareous to radiolaritic Triassic facies in Halstatt (Austtia), Lagonegro (S Italy) and Sicani Mts. (W Sicily), which are located just at the apex of the closing northern Tethyan arm and of the opening southern Tethyan arm.

DISCUSSION

Some points need to be stressed.

1. The Early Permian marine belt ranging from Tuscany to Sicily may have extended westward to the Tunisian and Algerian Maghtehian chain. However, the internal Apennine units containing these important Permo-Carboniferous marine deposits in the Apennines and Sicily are less exposed in the Maghrebian chain where they may be tectonically buried under the more internal Kabylid nappes or submerged in the western Mediterranean offshore.

2. The famous thick mid to Late Permian marine deposits of Tunisia outcropping in the Djebel Tebaga near Medenine and cored from the well at Bir Soltane (Douvillé *et al.* 1933; Skinner & Wilde 1967; Vachard & Razgallah 1993) are structurally quite distinct from the Permian of Sicily. In fact they represent an epi-Baikalian cover, faulted and tilted before Triassic deposition and gently folded during neo-Alpine deformation. It is located at the south-western edge of the Pelagian Block, close to the limit with the southern Atlas chain and the almost stable Sahara Platform. Moreover, the mixed shaly-sandy and carbonate facies of shelf environment shows a clear shallowing upwards (Bellerophon dolomitic facies and red Triassic continental sandstones), whereas the deep water Permian strata of western Sicily is followed by deep water Triassic limestones and radiolarites. However, the approximately 1700 m of marine mid to late Permian exposed in southern Tunisia clearly suggests an important subsiding basin possibly parallelling the two opposite southern (Sahara Platform) and northern (Sardic-Calabrid-Kabylid-Betic) belts characterized by continental Permian. The E-W trending marine Permian of Tunisia is unconformably sealed westward mainly by onlapping Cretaceous deposits, before being tectonically buried under the Maghrebian thrust belt. The Maghtebian thrust sheets are usually detached from Triassic evaporitic layers. So, there is quite a chance to have a buried E-W trending marine Permian basin filling incorporated within the "basement" all along the Maghrebian chain as far as the northern Moroccan Atlantic coast.

3. According to Kahler (1974) the Fusulinid fauna from Tunisia is immediately younger (Murghabian) than and has no species in common with the one from Sicily, althotigh a short time overlap exists between the two faunas. This is mirrored by a quite different original position of the two areas and may suggest a physical barrier (*e.g.* a deep although narrow sea-way) separating the Tunisian shelf to the south from the Sicilian basin and shelf to the north.

4. There is a prominent marine character of both late Carboniferous and early Permian depositional envitonments of the Tuscan to Sicilian Apenninic to Maghrebian belt as compared with the remaining three other palinspastic units now assembled into the Italian area and chatacterized by the usual European continental facies (with exception of the eastern Southern Alps and Dinarides). This is well consistent with and needed to explain Triassic marine deposits practically surrounded by continental deposits (as for the Punta Bianca near La Spezia marine Early to Middle Triassic sequence with pillow-lavas) or

deep water facies apparently isolated within shallow-water platforms (as for the Triassic Lagonegro basinal deposits and volcanics) (Vai 1994).

5. The reported South American affinity of the Moscovian Tuscan conodont fauna requires a connection which can be found across NW Africa. In fact, after the peak late Viséan transgression over most of NW Africa, marine sedimentation was reduced to an E-W trending wide belt including the Fourhal, Jérada, Colomb-Béchar, Reggan, Illizî Basins in the Sahara Platform, where it lasted until most of the Moscovian (Conrad *et al.* 1980; Fabre 1983; Legrand-Blain 1983). Marine Moscovian is also known from the SW Moroccan Meseta (W of Fkih ben Salah; Choubert & Faure-Muret 1956). This marine belt can be traced westward to South America in the Amazon Basin and the Northern Andes (Ferrari *et al.* 1977 for ref.). In the remaining part of the Meseta as well as in the Kabylid-Riff and Betic nappes, Permo-Carboniferous and Permo-Triassic continental deposits are only known. In the intermediate Riff and Atlas thrust belt no Permo-Carboniferous information is available because the individual thrusts are detached at the Triassic level. The NW Africa Moscovian sea was probably connected with the south Portuguese zone, where thick foredeep marine deposits as late as Moscovian are known, whereas continental Westfalian and Stephanian rocks were accumulating in the northern Portugal.

6. The reported Spanish affinity of the Moscovian corals from Tuscany suggests the way to connect the almost isolated late Carboniferous Cantabrian Basin with the world ocean system through a Corsica-southern France and eastern Spain corridor. In this respect, the rich Viséan marine fauna of the Montagne Noire (Mamet 1968), Mouthoumet, Pyrénées and Catalonia, followed by mid Carboniferous (Namurian-Westfalian p.p.) turbidites (Ebner 1991), is consistent with the suggested connection. The same applies to the Tournaisian (Krylatov & Mamet 1966) of the N Corsica Capitello limestone and overlying shales cut by rhyolitic dykes and followed by late Westfalian megafloral deposits.

7. As a conclusion one can say that a series of new field data (Catalano *et al.* 1991; Vai 1994; papers in this volume), together with reasonable assumptions based on indirect evidences, would suggest an early to mid Permian sea-way cutting across North Africa and Iberia (*i.e.* separating Gondwanaland from Laurussia) as claimed by Vai (1994). Further support to this hypothesis may derive from the contrasting distribution pattern of provincial floral (Chaloner & Meyen 1973) and continental vertebrate (Romer 1973; Millsteed B., Schneider J. W., pers. comm. 1995) elements passing from Permo-Carboniferous to late Permian-early Triassic. However, effective demonstration of this idea can only derive from either subsurface data beneath the Atlas thust belt or submarine drilling along the Moroccan Atlantic continental margin.

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Palaeogeographic maps of Moscovian and Artinskian; contributions from the Netherlands

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ABSTRACT

Frequent marine bands in the early Westphalian of the Netherlands are replaced by peat marshes followed upwards by a braided-river/fluvial-plain system in the late Westphalian-Stephanian. Sediments are limited to the depocenters Stephanian. Asselian to Artinskian deposits are represented by Lower Rotliegende volcanoclastics, basaltic volcanics and sediments of continental environment.

KEY WORDS
Westphalian,
Stephanian,
Lower Rotliegende,
Variscan front,
basins,
tectofacies.

RÉSUMÉ

De nombreux niveaux marins du Westphalien inférieur des Pays-Bas sont remplacés vers le haut par des tourbes marécageuses suivies par des systèmes fluviatiles de plaine deltaïque au Westphalien supérieur-Stephanien. Les sédiments stéphaniens sont limités aux dépôts-centres. Les niveaux de l'Asselien à l'Artinskien sont représentés par des volcanoclastites du Rotliegende Inférieur, des basaltes et des sédiments d'environnement continental.

MOTS CLÉS
Westphalien,
Stéphanien,
Rotliegende inférieur,
front varisque,
bassins,
tectofaciès.

MOSCOVIAN TO GZHELIAN

The Moscovian deposits are represented, according to the current ideas, by approximately the interval of the Westphalian C to Stephanian. The constraint is provided by the age dating of Lippolt *et al.* (1984), which revealed an age of 311 Ma for the base of the Westphalian C. The exact chronostratigraphic position of the youngest sediments (? Stephanian) in the eastern Netherlands and adjacent part of Germany is still debated, since the palynological assemblages clearly indicate a younger age (Autunian) than the paleobotanical assemblages (Westphalian D; Van der Zwan *et al.* 1993). There is a tendency in Germany to place these sediments in the youngest part of the Carboniferous, the Gzhelian (Plein 1995). During the Moscovian, an important change in climate occurred from humid tropical conditions to a (semi-) arid climate, as documented by a change in soil type (Selter 1989; Van der Zwan *et al.* 1993).

In broad terms, the development of the Westphalian C to Stephanian deposits is quite similar throughout the onshore and offshore areas; the main difference consists of the amount of later erosion of the Carboniferous. For the Netherlands, one reference section has been compiled for the eastern Netherlands (Fig. 1).

The present-day outline of the Moscovian deposits (Fig. 2) in the Netherlands is mainly controlled by erosion and uplift owing to the Variscan deformation phase during the youngest Carboniferous. In large part of the Netherlands onshore and western offshore areas Bashkirian (Westfalian A/B) deposits underlie the Permian rocks. Compared to the Westphalian A and B, the younger Westphalian and Stephanian have been deposited under increasing tectonic instability as the Variscan front prograded northward. This resulted in the intermittent tectonic activity of main fault zones, and at the end of the Carboniferous led to the deformation of the foreland-basin infill. The Variscan phase is considered to have accentuated the differences in subsidence during the Moscovian. In the basins, up to 1200 m of Westphalian C to Stephanian sediments have been preserved; in the uplifted areas, sediment thicknesses of this interval were probably not over 750 m and presumably consist of fine-grained sediments.

At the onset of the Westphalian C, extensive peat marshes existed over the entire Netherlands offshore and onshore areas. Marine bands, which frequently occurred in the Westphalian A and B, occured only sporadically in the Early Westphalian C. During the late Westphalian C, owing to an abrupt influx of coarser grained sediments, these marshes were replaced by an extensive braided-river/fluvial-plain system. Sediments came basically from three different source areas, the Rhenish Massif in Germany in the southeast, the Mid North Sea High in the north, and the Brabant Massif to the south (Fig. 2). There are minor differences in the onset and duration of these sandy influxes between the different parts of the basin. These sandy sediments were replaced in the early Westphalian D again by fine-grained sedimentation. The only exception is formed by the Campine Basin in north-eastern Belgium and the south-eastern Netherlands, where the sandy fluvial deposits are limited to the early Westphalian D interval (Paproth *et al.* 1983). In other areas, during the Westphalian D deposition took place on a semi-arid flood-plain with sheet floods and braided rivers. Soil types indicate that these flood-plains became better drained during this timespan.

The occurrence of the ? Stephanian deposits is limited to the depocentres of the Moscovian basins in the eastern Netherlands and probably the northern Netherlands offshore area. An unconformable contact of the Stephanian with the underlying Westphalian D sediments is assumed (Tantow 1993; Van Adrichem, Boogaert & Kouwe 1993-1996). Stephanian deposits are formed by well-drained distal floodplain deposits, with minor braided channels (Van der Zwan 1993).

ASSELIAN TO ARTINSKIAN

The Asselian to Artinskian deposits in the

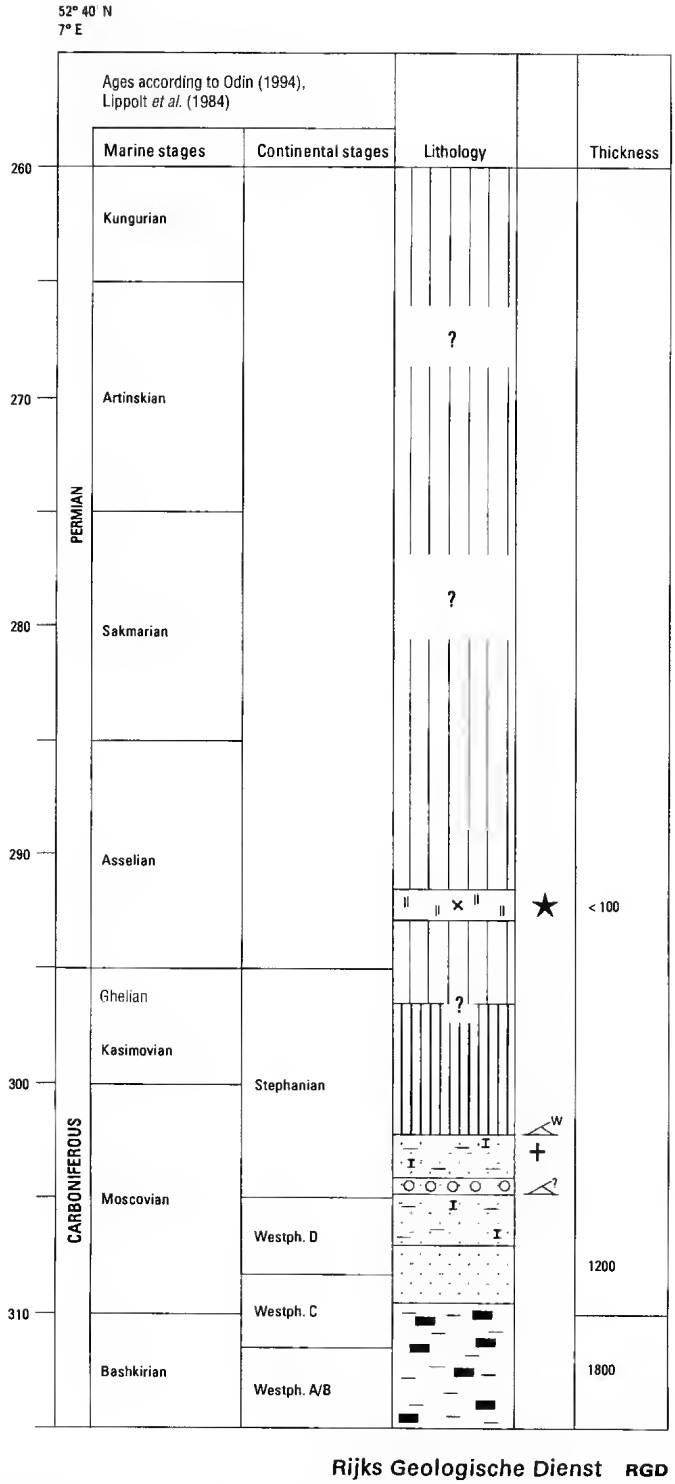
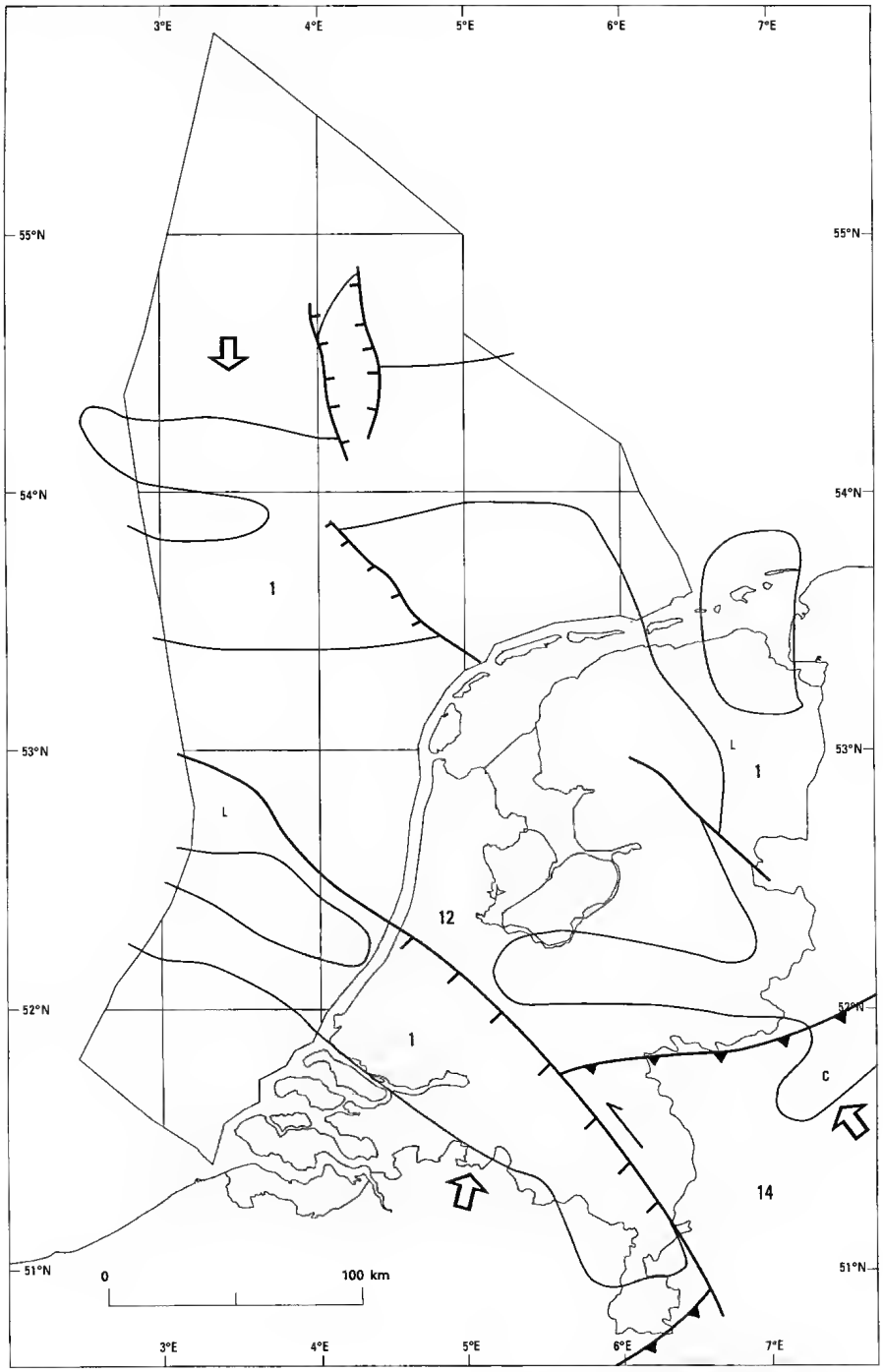


FIG. 1. — Reference columnar section for eastern Netherlands. See Vai & Venturini (this volume) for legend.

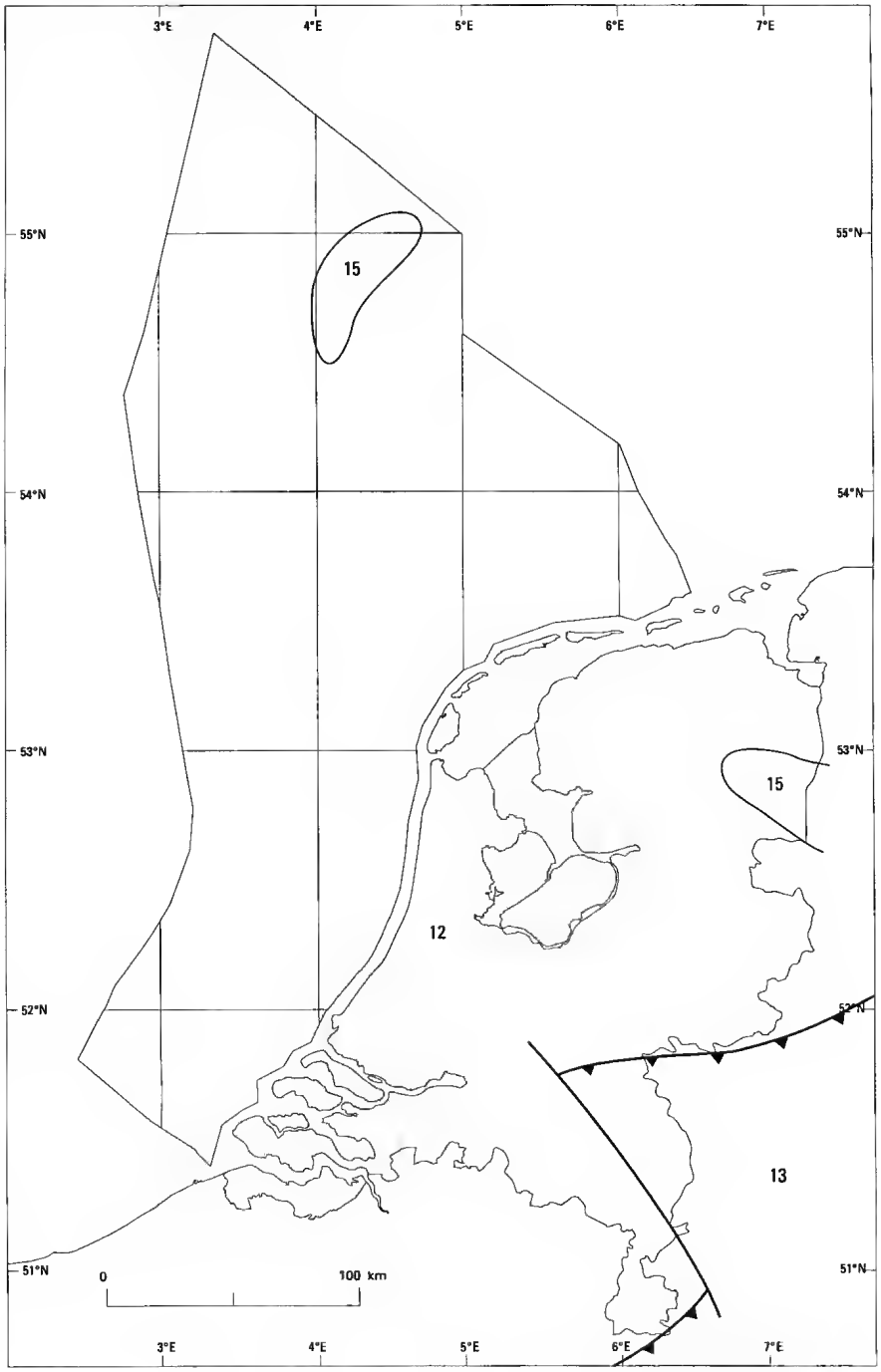
Moscovian to Gzelian



Rijks Geologische Dienst RGD

FIG. 2. — Deposits of Moscovian age in the Netherlands. See Vai & Venturini (this volume) for legend.

Asselian to Artinskian



Rijks Geologische Dienst RGD

FIG. 3. — Lower Rotliegende volcanoclastics of Asselian to Artinskian age in the Netherland onshore and offshore areas. See Vai & Venturini (this volume) for legend.

Netherlands are represented only in small areas of the Netherlands by sediments. The deposits of this interval are most likely represented by the Lower Rotliegend volcanoclastics. These volcanoclastics occur in two separate areas, namely in the Ems Low in the eastern Netherlands onshore area and the Central North Sea Graben in the offshore area (Fig. 3). Volcanic activity in the Netherlands and Germany occurred in response to wrench movements along Variscan fault zones (Ziegler 1990).

The volcanoclastics in the Ems Low represent the western outliers of a more extensive area of volcanic activity in Germany (Plein 1995). The volcanoclastics consist of red-brown to green spilitic, basaltic volcanics and mudstones. Several stacked lava flows occur in the succession. The thickness of the volcanics reaches a maximum of 80 m. The age remains speculative, but, based on indirect evidence, is assumed to be Asselian (Plein 1995).

In the Central North Sea Graben the sequence reaches a thickness of almost 150 m. The volcanics consist here of massive tuffs and lavas up to several tens of meters thick, interbedded with claystones and subordinate sandstones. No reliable datings are available for these volcanics (Plein 1995). They are assumed to have an Asselian age.

Following the Asselian, a long period of non-deposition followed; sedimention was only resumed during the youngest stage of the Permian, the Tatarian.

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On the biostratigraphy and cyclostratigraphy of the Moscovian Stage in the type area

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ABSTRACT
Moscovian Stage deposits are widespread in Russia. The stage was established in 1890 by Nikitin. It is subdivised in four horizons: Vereya, Kashira, Podol'sk and Myachkovo. The subdivisions of the stage are based on studies of brachipods, foraminifera, conodonts, ammonites, bivalves, rugosans and plants. In this paper, new data are due to the correction of the standard section of the Moscovian Stage and its new interpretation. Cyclostratigraphy analysis based on the geological history of the region and its eustatics is a new aspect of the research presented in this paper.

KEY WORDS
Moscovian, Carboniferous, biostratigraphy, cyclostratigraphy, Moscow Syncline.

RÉSUMÉ
Les dépôts du Moscovien sont largement répandus en Russie. Cet étage a été défini en 1890 par Nikitin. Il est subdivisé en quatre horizons : Vereya, Kashira, Podol'sk et Myachkovo. Les subdivisions de l'étage sont fondées sur l'étude des brachiopodes, foraminifères, conodontes, ammonites, bivalves, rugueux et plantes. Dans cet article, les nouvelles données proviennent de la révision de la coupe standard de l'étage et de ses nouvelles interprétations. L'analyse cyclostratigraphique fondée sur l'histoire géologique de la région et de son eustatisme est un nouvel aspect de la recherche présenté ici.

MOTS CLÉS
Moscovien, Carbonifère, biostratigraphie, cyclostratigraphie, synclinal de Moscou.

The Moscovian Stage deposits as well as the Middle Carboniferous ones as a whole are widespread in Russia and mineral deposits, including oil and gas, are rather common in these sediments. Subdivision and correlation of the Moscovian polyfacial deposits connected with different climatic zones (subtropical and boreal) represent the essential element of geological mapping and exploitation. Tendency to adequate reliability, precision of stratigraphic scales and high degree of correlations achievement caused the necessity to reinvestigate of the stage and substage stratotypes.

The Moscovian Stage was established by Nikitin in 1890 in the vicinity of Moscow. The upper limit of the stage was defined at the base of Gzhelian limestones.

The Moscovian, according to the ideas of Ivanov (1926) who had established the fundamental principles of the modern views on the volume of this stage and its subdivisions based on the studies of the depositional sequence in the southern part of the Moscow Syneclise, was subdivided into four horizons: Vereya, Kashira, Podol'sk and Myachkovo. The Tegulifera Horizon (the Kasimovian Stage) was considered to be a part of the Upper Carboniferous. Faunal assemblages of the Moscovian as a whole, as well as those of its subdivisions based on studies of brachiopods, foraminifers, conodonts, ammonites, bivalves, rugosans, plants, are relatively well known, zonal scales being established on the basis of some of these studied groups. Numerous publications are devoted to the Moscovian Stage in the type area, which most important are those by Ivanov (1926), Ivanova & Khvorova (1955), Rauser-Chernousova *et al.* (1951). Some papers are published during the last 20 years by Shik (1971), Makhlina (1972, 1976), Makhlina & Shik (1983), Makhlina *et al.* (1984), Goreva (1984), Solovieva (1984, 1986).

New data included in the present paper were obtained by the correction of the standard section of the Moscovian Stage and its new interpretation.

The lower boundary of the Moscovian Stage, according to the traditional views, coincides with the lower boundary of the Vereya Horizon. Changes in the standard section interpretation were caused by the discovery of a gap in the stratotype section of the Kashira Horizon, where deposits of the Tsna unit, established by Solovieva (1984, 1986) in the Tsna River basin (Ryazan-Saratov depression) in the eastern part of the Moscow Syneclise, are absent. Cyclostratigraphical analysis of the Moscovian Stage based on the geological history of the region and its eustatic tectonics is the new aspect of the research presented in this paper.

The Moscovian Stage in the type area is represented by marine deposits, *i.e.* by continuous series of transgressive deposits (130-150 m thick), in which sands and clays are gradually replaced by clayey and pure limestones. Subhorizontal bedding and cyclicity of deposits give opportunity to identify and follow up horizons, formations and relatively small subdivisions (subformations and members) in this region, and to identify cycles of different order.

If the Carboniferous system is considered to be a cycle of the third order, Middle and Upper Carboniferous (Pennsylvanian) are cycles of the fourth order. The Middle Carboniferous corresponds to a tectono-eustatic cycle of the fifth order, the Moscovian and Kasimovian stages to cycles of the sixth order (Table 1). According to Tikhomirov (1988), the latter includes the three units corresponding to three phases of the transgression: initial (α), maximum (β) and terminal, or regressive phase (γ). Cycles of the sixth order may be complete or shortened, the former consisting of three cycles of the seventh order, the latter of two cycles of the same order, the initial phase being absent. These cycles could be followed up in different facies throughout a region, and their formation corresponds to the maximum tectono-eustatic changes of basin level. The Aza, Vereya and Tsna subdivisions apparently correspond to the cycle of the seventh order, or to the initial phase of the transgression (α) (Table 1). The combined Kashira, Podol'sk and Myachkovo horizons correspond to the cycle of the seventh order, or to the maximum phase of the transgression (β), whereas three horizons of the Kasimovian Srage of the Upper Carboniferous correspond to a regressive phase (γ). Within the cycles of the seventh order there

TABLE 1. — Subdivision of the Moscovician of the Russian Platform.

Regional scale	Local scale Moscow Synclise			Cyclostratigraphy scale order of cycles						
				IX	VIII	VII	VI	V	IV	III
Horizon	Formation	Subformation	Member	Horizon (Formation)	Substage		Stage	Series	Subsystem	System
Krevyakino	Krevyakino	Voskresensk		Krevyakino	Krevyakinian	γ	Kazimovian	Upper	Pennsylvanian	Carboniferous
		Suvorovo								
Myachkova		Peski		Peski	Myachkovian β3	β	Moscovian	Lower		
		Novlinskoe		Novlinskoe						
Podol'sk	Podol'sk	Shchurovo		Shchurovo	Podolskian β2					
		Ulitino		Ulitino						
		Vas'kino		Vas'kino						
Kashira	Kashira	Smedva	Smedva	Smedva	Kashirian β1					
			Rostislavl'							
		Lopasnya	Lopasnya	Lopasnya						
			Khatum							
		Nara	Nara	Nara						
			Polustova Gora							
		Tsna		Tsna	Tsnian? α3	α				
Vereya	Vereya	Upper	Ordynka		Vereyan α2					
			Alyutovo							
		Lower	Shat							
Melekess	Aza			Aza	α1					

are smaller cycles - those of the eighth order, corresponding to separate horizons (substages in the proposed cyclostratigraphic scale, Table 1) and those of the first order, corresponding to subformations (horizons in the proposed cyclostratigraphic scale, Table 1).

Every stratigraphic unit of any rank can be subdivided into two parts: lower, corresponding to the transgressive phase of sedimentation, and upper, corresponding to the regressive phase. Contemporaneous stratigraphic units of different facies, which were formed in the paleobasin as a lateral sequence of rocks reflect, near-shore, periferal, shallow-water and relatively deep-water environments. Periodicity in the distribution of faunal assemblages, which always show maximum diversity in a transgressive part of a cycle and low diversity in its regressive part (Makhlina & Shik 1983), is a characteristic feature of all simultaneously formed polyfacial stratigraphic units corresponding to the cycles (Figs 1-3). Boundaries between these units correspond to historico-geological changes of sedimentation patterns, *i.e.* to changes in abiotic environment taking place simultaneously in the whole region (Makhlina 1996).

The main criteria for distinguishing and tracing of transgressive-regressive cycles in which combination form stratigraphic units (formations, sub-

formations) are the following: sedimentological and faunistic content, features of texture, periodicity in the distribution of all groups of fauna in the section, as well as biostratigraphical characteristics for the definition of the geological age of the units. The sufficient methodical significance of the lithological-palaeoecological criteria, elaborated by Osipova & Belskaya (1967), should be emphasized in this respect.

Leaving aside the problem of the lower boundary of the Moscovian Stage, that is still discussed (Solovieva 1986; Alekseev *et al.* 1994), let us give brief characteristics of the stratotype sections of the horizons (formations, subformations), *i.e.* of units of the regional and local scales of the Moscovian Stage, accepted in Russia (Anonymous 1988, Table 1).

The Vereya Horizon (Formation), in order to reinvestigate the stratotype, was studied near the village Alyutovo on the right bank of the Pronja river, where it is lying transgressively on Lower Carboniferous deposits (Solovieva 1986) (Fig. 2-I). Red sand and clays, glauconite sandstones can be found in the base of the section, crinoid-bryozoan sandy limestones with foraminifers, as well as interbedding of crinoid limestones, variegated clays, marls with brachiopods and bryozoans overlying them (Ivanova & Khvorova 1955). The thickness of the formation in this section is 10 m, and in the region it changes from 10 to 35 m. The Vereya Formation is subdivided into two subformations, lower and upper (Anonymous 1988). Solovieva (1986) proposed the foraminiferal *Profusunella cavis*, *Aljutovella aljutovica*, *Al. artificialis* Zone. The typical assemblage of the Vereya Horizon (Formation) is represented by the following species of foraminifers: *Eostaffella mutabilis*, *Schubertella pauciseptata*, *Pseudostaffella subquadrata*, *Profusulinella cavis*, *P. parva*, *Aljutovella aljutovica*, *A. artificialis*, *A. scelnevatica*, *A. cubaea*, *A. elongata*.

Deposits of the Vereya Horizon (Formation) correspond to the conodont *Idiognathoides tuberculatus*, *Id. marginodosus* Zone. Characteristic species of the zone are *Idiognathoides donbassicus*, *Id. sinuatus*, *Id. fossatus*, *Id. corrugatus*, *Idiognathodus incurvus*, *Neognathodus atokaensis*, *N. bassleri*, *Diplognathodus coloradoensis*, *D. orphanus*, *Streptognathodus parvus*.

According to Solovieva (1984) and Alekseev (1994), the Vereya Formation *sensu* Ivanov (1926) is only characterized by the Alyutovo fusulinid and conodont assemblages. The overlying and underlying Shat and Ordynka members (Table 1) do not contain any other faunistic complex except Alyutovo age.

In the standard of the Moscovian Stage, the position above the Vereya Formation in the case of normal sequence is occupied by the Tsna unit distinguished by Solovieva (1984, 1986). In the stratotype section (Yambirnoye Quarry, Ryazan region, Fig. 1-II) it is represented by interbedding of detrital and dolomitized fine-grained limestones with greenish clays and marls, rarely with micro-grained dolomites (Fig. 2-II). The thickness of the subformation in the stratotype is 16.5 m (Table 1; Local Scale, 1988).

Deposits of the Tsna Subformation correspond to the Zone *Aljutovella priscoidea*, *Hemifusulina volgensis*. This typical foraminiferal assemblage, characterized by a high degree of similarity in all regions where these deposits are represented (the Russian Platform, the Donets Basin, the Cisuralian Depression, Urals, Tien-Shan, etc.), includes the following species: *Schubertella gracilis znensis*, *Sch. galinae*, *Ozawainella digitalis*, *Profusulinella prisca timanica*, *P. nuratovensis*, *P. jvata*, *Taitzehoella prolibrovichi*, *T. pseudolibrovichi*, *Aljutovella parasaratovica*, *A. saratovica*, *A. priscoidea*, *A. znensis*, *Hemifusulina dutkevichi*, *H. volgensis*.

FIG. 1. — Location map of the stratotype sections (I-X) of the Moscovian Stage (for the list of the sections, see figures 2, 3).

According to the preliminary investigations, the Tsna Subformation corresponds to the conodont *Neognathodus bothrops, Streptognathodus transitivus* Zone. The lower boundary is defined by the entry of *Neognathodus bothrops*, the upper one by the incoming of *Streptognathodus dissectus*. Deposits are characterized by an impoverished conodont complex. Typical species are as follows: *Neognathodus bothrops, Streptognathodus parvus, Idiognathodus delicatus, Id. obliquus, Diplognathodus coloradoensis.*
Deposits of the Tsna Subformation have a spotty distribution due to the transgressive bedding on it of the Kashira Horizon that corresponds to the beginning of maximum transgression (β_1, Table 1).

The Nara Subformation is represented by an interbedding of poorly coloured micrograined limestones and dolomites with biodetrital limestones and clay seams. The thickness of the deposits can reach 28 m (Fig. 2-III). Materials available give an opportunity to substantiate the recognition of the local *Hemifusulina kashirica, H. moelleri, Beedeina pseudoelegans* Zone. In the eastern sections of the southern part of the Russian Platform there are numerous *Neostaffella, Profusulinella pseudolibrovichi, Pr. colibrovichi, Pr. syzranica, Pr. mutabilis, Hemifusulina kashirica, H. pseudobochi, H. moelleri, Beedeina bona, B. ozawai, B. pseudoelegans, B.* cf. *proozawai, B. kayi*. The Nara Subformation corresponds to the conodont *Neognathodus bothrops, Streptognathodus dissectus* Zone. It is characterized by the following species: *Neognathodus bothrops, N. kashiriensis, Str. dissectus, Str. parvus. Diplognathodus coloradoensis* is very common.

The overlying Lopasnya Subformation is represented by interbedding of pinkish and greenish limestones, detrital, micrograined, with cherts, variegated marls, more rarely dolomites. Its thickness is 15-30 m (Fig. 2-IV). The subformation corresponds to the local *Moellerites lopasniensis, Beedeina ozawai, Fusulinella subpulchra* Zone (Solovieva 1986). The following complex is characteristic: *Ozawainella stellae, Fusiella praecursor paraventricosa, F. praetypica, Neostaffella larionovae, Fusulinella subpulchra, Hemifusulina moelleri, H. kashirica communis, H. splendida, Beedeina ozawai, B. paraozawai, B. pseudoelegans.*

The Rostislavl' member consists of two parts. The lower one is represented by interbedding of clays and limestones, or by unfossiliferous clays, or by dolomitic marls (bed 23, Fig. 2-IV), the upper one by sands, aleurolites, sandstones and conglomerate (bed 21, Fig. 2-V). The lower part corresponds to a regressive phase and terminates the Lopasnya Subformation; the upper part, being the transgressive one, corresponds to the base of the Smedva Subformation.

The Smedva Subformation, or according to Ivanov (1926) "dolomites of Smedva", contains micrograined dolomites and detrital limestones (Fig. 2-V). It was referred to the Podolsk' Horizon by Ivanov and Solovieva, many of the subsequent authors assigned this subformation to the Kashira Horizon. "Dolomites of Smedva" represent lagoonal rocks characteristic of a regressive phase. This environment was unfavorable for fusulinids. That is why deposits of the Smedva Subformation are very poorly characterized by this group of fauna. The Lopasnya and Smedva subformations correspond to the conodont *Neognathodus medadultimus, Streptognathodus dissectus* Zone. The lower limit of the zone is defined by the incoming of *Neognathodus medadultimus*, the upper one by the entry of *N. medexultimus*. Characteristic species are as follows: *N. bothrops, N. medadultimus, N. colombiensis, Idiognathodus obliquus, I. delicatus, I. robustus, Streptognathodus dissectus, Diplognathodus coloradoensis*. This zone can be subdivided into two local subzones, each with a characteristic assemblage: Subzone *Neognathodus bothrops, N. medadultimus*, corresponding to the Lopasnya Subformation, and Subzone *N. medexultimus* corresponding to the Smedva Subformation. The volume of the former sub-zone is designated by the coexistence of *N. bothrops* and *N. medadultimus*, the characteristic complex being represented by *N. bothrops, N. medadultimus, Streptognathodus dissectus, Idiognathodus obliquus*. The volume of the latter subzone is designated by the presence of *Neognathodus medexultimus, Streptognathodus dissectus, Idiognathodus obliquus, I. robustus.*

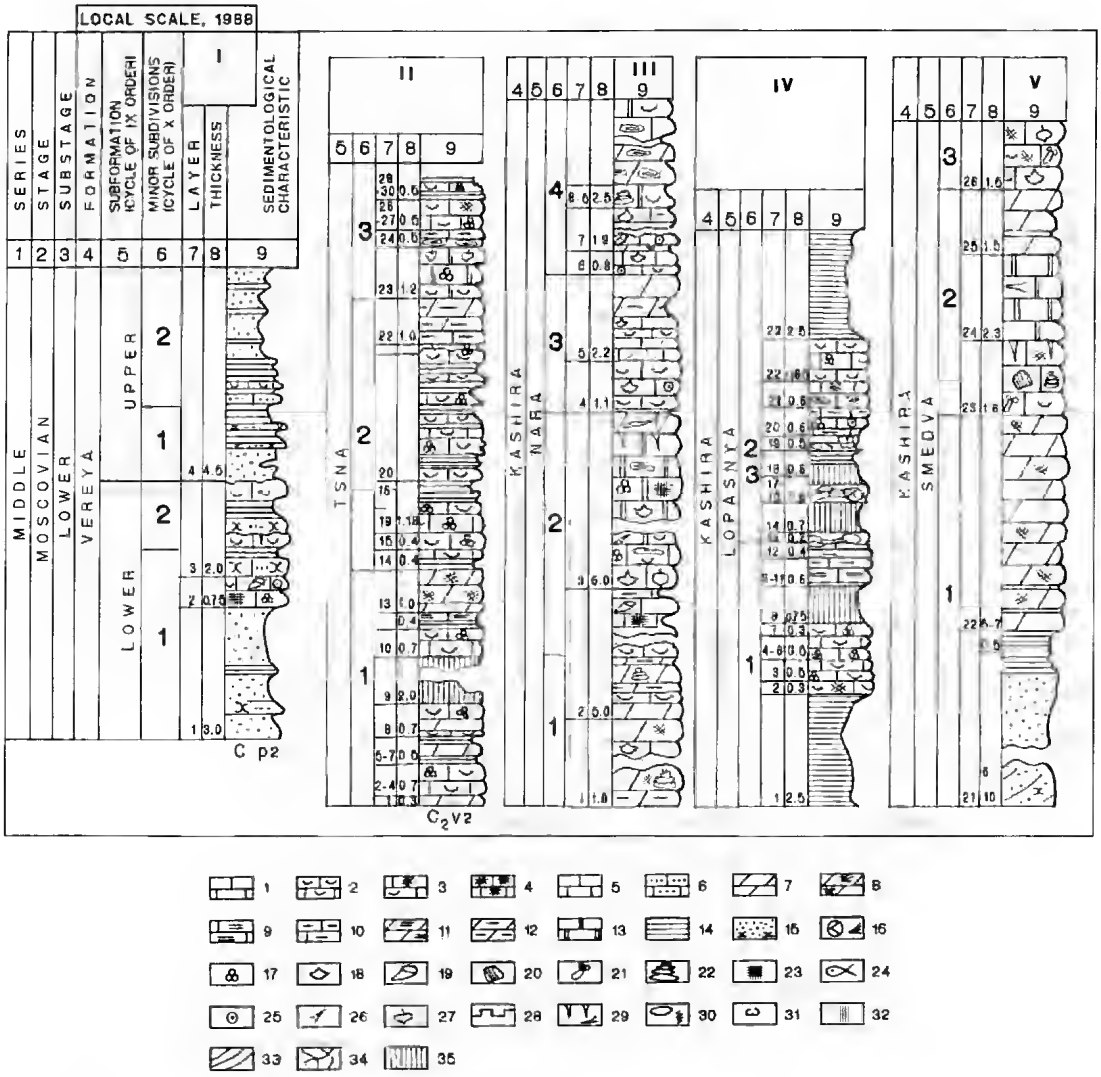

FIG. 2. — Sections of the Moscovian Stage (Veroya, Tsna and Kashira beds): **I**, outcrops near the Alyutovo village, right bank of the Pronja River (Solovieva 1986), lectostratotype of the Vereya Formation; **II**, Yambirnoye Quarry near the Yambirnoye village, left bank of the Tsna River (Solovieva 1986); the Tsna Subformation holostratotype; **III**, outcrops along the Oka, Nara, Protva, Besputa rivers; section of the Nara Subformation of the Kashira Formation (Ivanova & Khvorova 1955, fig. 13); **IV**, outcrop near the Lapino village at the left bank of the Lopasnya River (near the Khatun village) (Solovieva 1986); stratotype of the Lopasnya Subformation, **layer 1**, Khatun member; **layer 23**, Rostislavl'member, the lower part; **V**, outcrops along the Oka, Nara, Protva, Besputa rivers; sections of the Smedva Subformation of the Kashira Formation: **layer 21**, Rostislavl' member, the upper part (Ivanova & Khvorova 1955, fig. 13).

Legend for figures 2-3. Deposits **1-16**; **1**, limestone; **2**, detrital or biomorphic-detrital limestone; **3**, sludge limestone; **4**, micrograined limestone; **5**, coprolite-detrital limestone; **6**, lime sandstone; **7**, dolomite; **8**, micrograined dolomite; **9**, clayey limestone; **10**, marl; **11**, clayey dolomite; **12**, dolomite marl; **13**, dolomitized limestone; **14**, lime and dolomite clay; **15**, sand silt, sandstone; **16**, fragments of chert and limestone. Fossils **17-29**; **17**, foraminifers; **18**, brachiopods; **19**, solitary corals; **20**, colonial corals; **21**, bivalves; **22**, gastropods; **23**, bryozoans; **24**, fishes; **25**, crinoids; **26**, echinoids; **27**, algae; **28**, algae Ivanovia tenuissima; **29**, traces of mud-eaters; Secondary alterations, structure and other signs **30-35**; **30**, cherts; **31**, caverns; **32**, stylolites; **33**, cross-bedding; **34**, limestone breccia; **35**, gap.

The Podol'sk Horizon (Formation), a maximum phase of the Moscovian transgression (β_2), is represented mainly by biomorphic limestones with seams of micrograined dolomites, greenish

marl and clays; the total thickness is 25-40 m. Three subformations can be identified within this formation.

The lower one (Vas'kino Subformation) is represented by micrograined limestones and dolomites with biomorphic-detrital limestone seams; the thickness is 7-12 m (Fig. 3-VI). At the base, there are conglomerates and marls that could be traced regionally. The Vas'kino Subformation corresponds to the fusulinid *Fusulinella colaniae*, *Beedeina elegans* Zone. The characteristic complex is as follows: *Ozawainella kurakhovensis*, *Neostaffella rostovzevi*, *N. sphaeroidea*, *Taitzeheella librovitchi atelica*, *Fusulinella colaniae*, *Hemifusulina splendida*, *Beedeina elegans*, *B. ozawai*, *B. elshanica vaskinensis*, *Putrella triangula*.

The overlying Ulitino Subformation is similar to the Vas'kino in the sedimentological aspect but differs in the presence of limestone seams with the algae *Ivanovia tenuissima*. The thickness of the deposits is 12-18 m (Fig. 3-VII). The subformation corresponds to the local *Fusulinella*

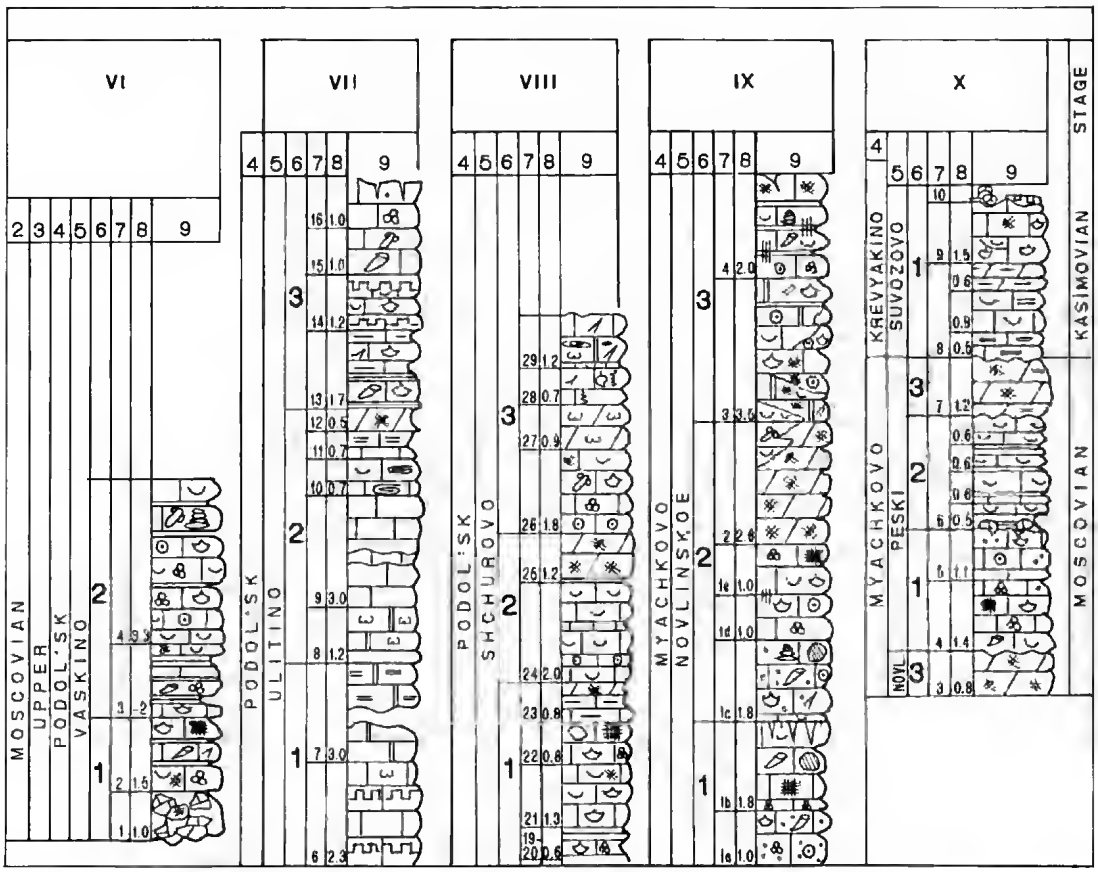

Fig. 3. — Sections of the Moscow Stage (Podol'sk, Myachkovo horizons); **VI**, sections in the basin of the Oka River east of the Kashira town, near Bolshoye Huno village, pogost Rostislavl', and near Vas'kino village; section of the Vas'kino Subformation of the Podol'sk Formation (Ivanovan & Khvorova 1955, fig. 20). **VII**, Quarry near the town Podol'sk; stratotype of the Podol'sk Formation (Ulitino Subformation) (Ivanova & Khvorova 1955, fig. 23); **VIII**, Quarry near the town Podol'sk, stratotype of the Podol'sk Formation (Shchurovo Subformation) (Ivanova & Khvorova 1955, fig. 23), **IX**, Quarry near the town Podol'sk hypostratotype of the Novlinskoe Subformation of the Myachkovo Formation (Ivanova & Khvorova 1955, fig. 23); **X**, Afanasievo Quarry near the Afanasievo village on the right bank of the Moskva River, section of the Myachkovo-Krevyakino boundary layers (Middle/Upper Carboniferous boundary); **layer 6**, "lower conglomerate"; **layer 7**, "dolomite of Turnovo"; **layer 8**, "gamasha"; **layer 9**, "sharsha"; **layer 10**, "upper conglomerate". Hypostratotype of the Peski Subformation of the Myachkovo Formation; it is near Peski railway station, on the left bank of the Moskva River (Makhlina *et al.* 1972, 1984).

vozghalensis, Fusulina litinensis Zone, the following complex being considered as a characteristic one: *Fusiella pulchella, Neostaffella ozawai, Ozawainella mosquensis, Fusulinella vozhgalensis, Hemifusulina stabilis, H. polasnensis, Fusulina ulitinensis, F. panconensis, Putrella brazhnikovae.*

The uppermost part of the Podol'sk Formation is identified as the Shchurovo Subformation represented by dolomites, biomorphic limestones with greenish marl and clayey limestone seams. Limestones are often dolomitized and siliceous. The thickness of the deposits is 8-12 m (Fig. 3-VIII). The Shchurovo Subformation corresponds to *Beedeina kamensis, Putrella brazhnikovae, Ozawainella mosquensis* Zone with accompanying characteristic complex of *Fusulinella bocki, F. vozghalensis, B. elegans, B. shellwieni, B. elshanica.*
Deposits of the Podol'sk Horizon correspond to the conodont *Neognathodus medexultimus, Idiognathodus podolskensis* Zone. The lower limit of the zone is defined by the entry of these two species, the upper one by the incoming of *Neognathodus roundyi*. The conodont complex as a whole is not characteristic enough, the following species being typical: *Idiognathodus podolskensis, I. magnificus, I. delicatus, Neognathodus medadultimus, N. medexultimus.*

The Myachkovo Horizon (Formation) accomplishes the maximum phase of the Moscovian transgression (β_3). It is represented by biomorphic limestones with micrograined dolomite seams and lightcoloured marl lenses. The total thickness of the deposits is 17-37 m. The formation is divided into two subformations.

The lower one, Novlinskoe Subformation, is represented by various limestones (detrital, biomorphic-detrital) with micrograined limestone and dolomite seams, coral-fusulinid limestones being typical of its lower part (Fig. 3-IX). The thickness of the deposits is 10-23 m. Deposits of the subformation correspond to *Fusulinella bocki, F. rara, Beedeina samarica* Zone. The characteristic complex includes *Schubertella myachkovensis, Fusiella typica, Neostaffella paradoxa, N. sphaeroidea, Fusulinella bocki, F. bocki pauciseptata, F. fluxa, F. mosquensis, F. rara, Beedeina samarica, Pulchrella pulchra, Hemifusulina bocki, H. stabilis, Fusulina cylindrica.*

The upper one, Peski Subformation, is represented by biomorphic-detrital limestone with lenses of lightcoloured marls and clays. "Turaevo" micrograined dolomite at the top accomplishes the maximum phase of the Moscovian transgression. The thickness of the deposits is 7-15 m (Fig. 3-X). Deposits of the Peski Subformation correspond to the local *Fusulinella podolskensis, F. cylindrica domodedovi* Zone. The data available, especially those concerning fusulinid distribution (Makhlina *et al.* 1972) give an opportunity to indicate complex typical of the deposits of the Peski Subformation: *Schubertella mjachkovensis, Ozawainella mosquensis, Fusulinella bocki, F. rara, F. podolskensis, F. helenae, F. mosquensis, F. kumpani, Hemifusulina bocki, Fusulina cylindrica domodedovi, F. mosquensis, F. mjachkovensis, F. pachrensis, F. fortissima.*

The Myachkovo Horizon (Formation) corresponds to the conodont *Neognathodus roundyi, Streptognathodus cancellosus* Zone. The lower limit of the zone is defined by the entry of *Neognathodus inaequalis, N. roundyi*, the upper one by the incoming of *S. subexcelsus, Idiognathodus fisheri* and by the disappearance of *Neognathodus* species. Index species are dominating in this complex, *N. medexultimus, N. inaequales, Idiognathodus delicatus, I. trigonolobatus* being characteristic ones. The zone is subdivided into two parts considered nowadays to be local subzones. The Novlinskoe Subformation corresponds to the *Neognathodus inaequales* Subzone, characterized by the acme of the index species. The Peski Subformation corresponds to the *N. roundyi* Subzone, *i.e.* to the period of *N. roundyi* mass development and incoming of *N. dilatatus* and *Idiognathodus trigonolobatus.*

The position of the upper boundary of the Moscovian Stage, *i.e.* the Middle/Upper Carboniferous, is still discussed at present time. This boundary was established by Ivanov (1926) in outcrops and quarries along the Moskva river and its tributaries (in Myachkovo, Suvorova Gora, Krevyakino and other localities). All these

localities are connected to a separate synsedimentary elevation in the Moscow zone of elevations and are characterized by varying facies of the boundary beds, as well as by numerous erosional surfaces with an intraformational conglomerate interbed. Some marker beds traced by Ivanov (1926) in the boundary beds in this region got their own names: bed 7 - "svinya", or "dolomite of Turaevo" (Makhlina *et al.* 1972) (Fig. 3-X) - lightgreen argillaceous micrograined dolomite; bed 8 - "garnasha" - interbedding of green, red clays and marls, limestones, sometimes with conglomerate interbeds. In some sections, this member is replaced by dolomitic marls and argillaceous limestones (Fig. 3-X); bed 9 - "sharsha" - white micrograined nonhomogeneous "conglomerate-like" limestone with caverns.

The position of the upper boundary of the Moscovian Stage, according to the conclusions based on brachiopods and foraminifera studies, is changing within the interval from "the lower conglomerate to the base of the upper conglomerate", *i.e.* within the interval from bed 6 to bed 10 on Fig. 2-X (Ivanov 1926; Ivanova & Khvorova 1955; Bolkhovitinova 1937; Rauser-Chernousova & Reitlinger 1954; Makhlina *et al.* 1972). Further studies of the lower conglomerate interbed (bed 6 on Fig. 3-X) underlying "dolomite of Turaevo" showed that this conglomerate was from intraformational origin and not of interstagial one, because all these interbeds contained fusulinids of *Fusulina cylindrica* Zone, indicating the Myachkovo (Peski Subformation) age of the "lower conglomerate" (Makhlina *et al.* 1972).

The complex of foraminifers above the "dolomite of Turaevo" (in beds 8-9, *i.e.* in "garnasha" and "sharsha") is represented by numerous small foraminifers and fusulinids with a wide vertical distribution, *Ozawainella angulata*, *Globivalvulina* ex gr. *granuloza*, *Schubertella mjachkovensis*, *Endothyra* sp. among them. Recently, few oppressed *Obsoletes obsoletes* were found in these beds. Mass *Obsoletes* enter above the bed 9 ("sharsha"). Therefore, we draw the boundary between the Myachkovo and the Krevyakino horizons (*i.e.* the Middle/Upper Carboniferous boundary) at the top of the "dolomite of Turaevo" (bed 7 on Fig. 3-X) between the two conglomerates, the lower one and the upper one.

Conodont distribution in the boundary beds demonstrates that the "garnasha"-"sharsha" beds should be assigned to the Kasimovian stage, *i.e.* to the local Subzone *Idiognathodus arendti* of the *Streptognathodus oppletus* Zone (the Krevyakino Horizon). The lower limit of the subzone is defined by the incoming of *Idiognathodus arendti*, *I. fisheri*, *Streptognathodus subexcelsus*, *S. oppletus*, the upper one by the entry of *S. sagittalis* and the disappearance of *Idiognathodus trigonolobatus*. Characteristic species are as follows: *Streptognathodus subexcelsus*, *S. oppletus*, *S. excelsus*, *S. cancellosus*, *Idiognathodus trigonolobatus*, *I. fisheri*, *I. arendti*.

The upper boundary of the Myachkovo Horizon (Formation), established on the basis of cyclostratigraphic analysis at the top of the "dolomite of Turaevo", is proved not only by faunal distribution data but by also sedimentological and geochemical data. Bed-by-bed comparison of detrital limestone microstructures on the Myachkovo-Krevyakino boundary demonstrates that in the former cloddy pelletal cement structures dominate, whereas in the latter (the Suvorovo and Voskresensk subformations) micrograined ones dominate. Comparison of the geochemical coefficients in the boundary beds also demonstrates the difference in the quantitative content of microelements: in carbonate rocks and in clays and marls in the Novlinskoe and Peski subformations, it is respectively 10 and 2000 times more, than in similar rocks of the Suvorovo and Voskresensk subformations. This level, therefore, designates the end of the Moscovian transgression maximum phase (β_3) and the beginning of a regressive phase (γ). It corresponds to the Kasimovian time, characterized by the terrigenous supply with the microelemental content, different from the Moscovian, by facies variability in the zone of synsedimentary elevations, followed by the erosion and prevailing of unfavorable environments for many groups of fauna, particularly foraminifers (Makhlina 1976; Makhlina *et al.* 1972).

Based on the data obtained from cyclostratigraphical analysis of the Middle/Upper Carboniferous deposits in the type area, one may conclude that the Kasimovian/Gzhelian bounda-

ry was more significant than the Moscovian/Kasimovian one, because the Kasimovian Stage represented the terminal phase of the Moscovian transgression, whereas the Gzhelian Stage corresponded to the maximum phase of the following, the Gzhelian/Asselian transgression (both the Moscovian and the Gzhelian/Asselian transgressions represent cycles of the sixth order). This cyclostratigraphical boundary supports the views of Nikitin (1890), who proposed to draw the boundary between the "Moscow Series" and the Gzhelian Stage below the limestones of Gzhel.

Taking into account everything mentioned above, one may come to the conclusion that almost each of the subdivisions of Kashira, Podol'sk and Myachkovo horizons (formations) are characterized by zonal conodont and fusulinid assemblages, and can be traced in different facies all over the major part of the Moscow Syneclise and other regions of the Russian Platform, and also outside of it. It gives the opportunity to raise the rank of these subdivisions and to regard them as the horizons (cycles of the eighth order) of the Russian Platform Regional Scale (Table 1). We believe also that the horizons established by Ivanov in 1926 (the Vereya, Kashira, Podol'sk and Myachkovo - cycles of the eighth order) correspond to stages, as it has been demonstrated by Ivanova in 1955 and proved by numerous data, obtained during the following years. However, in May 1995, the Interdepart-mental Stratigraphic Committee of Russia decided to consider horizons of the Moscovian Stage of the Global Scale as substages with their own names. As to the Tsna Subformation, the problem of its rank still remains debatable (should it be a horizon or a substage?). Solovieva considered the Tsna beds to be of a stage rank. It can be traced in the Russian Platform, as well as in Tien-Shan, Donets Basin, Urals and other regions.

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Stratigraphic correlation of the Upper Permian deposits from the south of the Cis-Ural marginal Trough and the adjacent areas of the Russian Plate

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ABSTRACT
Studied in detail were about 100 sections of the Upper Permian marine and continental deposits from the South Cis-Urals: from the south-eastern edge of the Russian Plate and the Cis-Ural Trough. Characteristic complexes of marine and non-marine ostracodes were distinguished. All the regional stratigraphic units of the Upper Permian were characterized in detail from micropaleontologic point of view. Associated organic remains were specified: tetrapods, bivalves, miospores. Brief lithologo-facies descriptions of the sections from various structural zones are presented. Detailed correlations of the Upper Permian sections from the South Cis-Urals were carried out.

KEY WORDS
Upper Permian, stratigraphy, correlation, South Cis-Urals, Cis-Ural Trough, Russian Plate.

RÉSUMÉ
Une centaine de coupes dans les dépôts marins et continentaux du Permien supérieur du Cis-Oural sont étudiées en détail : de l'extrémité sud orientale de la plate-forme jusqu'à la dépression du Cis-Oural. Des assemblages d'ostracodes marins et continentaux sont distingués. Toutes les unités stratigraphiques régionales sont caractérisées en détail du point de vue micropaléontologique. Les bio-restes associés sont spécifiés : tétrapodes, bivalves, miospores. De brèves descriptions des faciès et de la lithologie sont présentées pour les différentes zones structurales. Des corrélations détaillées pour les coupes du Permien supérieur sont conduites.

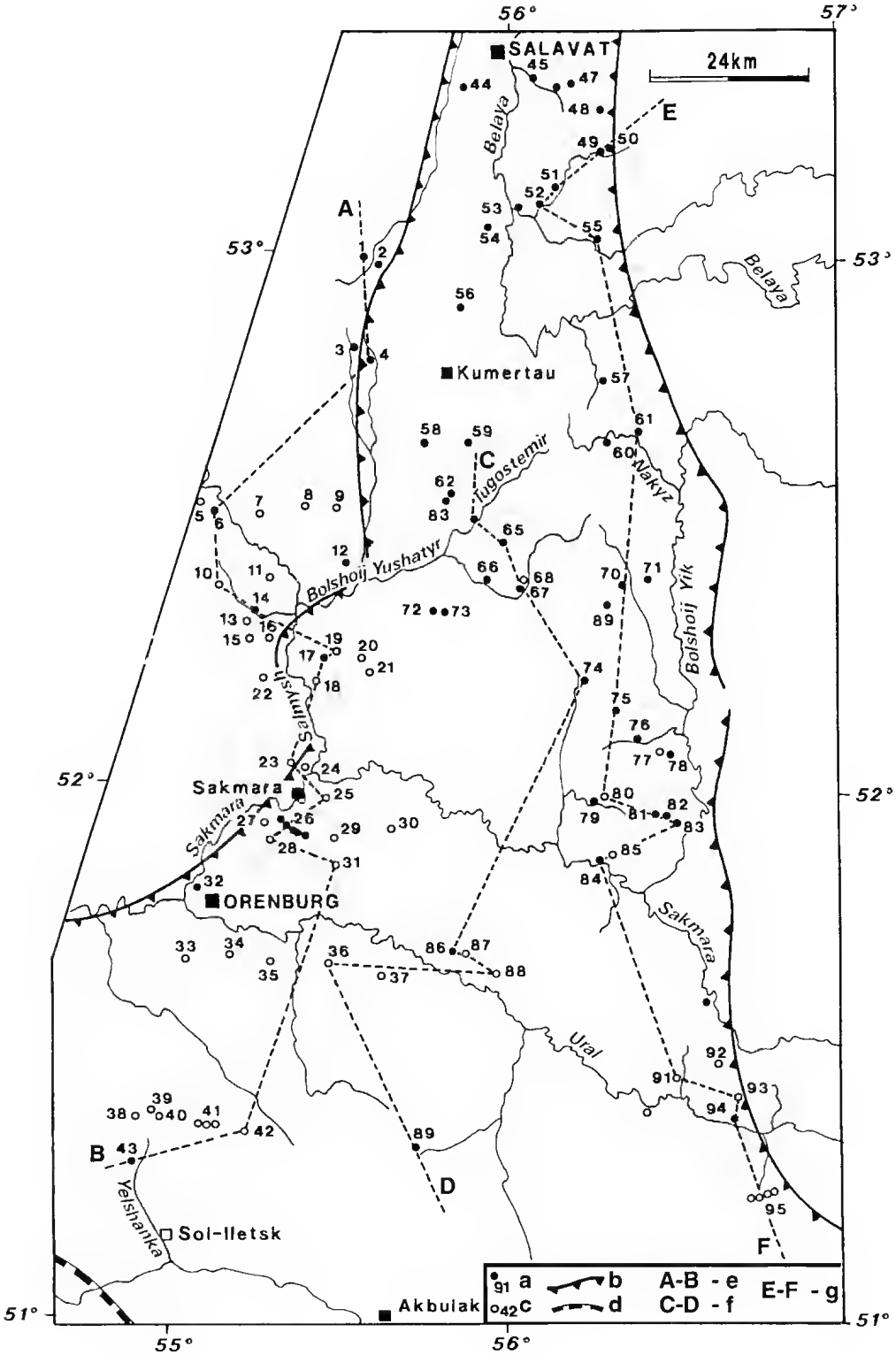
MOTS CLÉS
Permien supérieur, stratigraphie, corrélations, Sud Oural, Cis-Oural, plate-forme russe.

INTRODUCTION

The Permian system is distinguished for the wide-scale distribution of continental deposits in Gondwana and Laurasia. It is extremely difficult to divide or correlate these deposits due to their facial variations and scarcity of organic remains. The Upper Permian continental formations from the east of European Russia are exceptional in the respect, because diverse fossils have been found and studied there: ostracodes, bivalves, conchostracans, tetrapods, fishes, flora and miospores. Tetrapods and ostracodes are among those most studied. Due to their common occurrence and fast evolutionary variability, ostracodes have become the leading fauna in regional correlations. They may prove to be important for distant stratigraphic correlations as well.

The present paper deals with stratigraphic correlations and complex biostratigraphic description of the Upper Permian deposits from the southern Cis-Urals, one of the most complicated geologic regions embracing the junction zone of the south-east of the Russian Plate, Cis-Ural Marginal Trough and Peri-Caspian Depression. Special attention was paid to ostracodes, which formed the basis for section divisions and correlations. The research was founded on well and natural section descriptions made by the author in the process of geologic survey and thematic works, and on the materials presented in the papers by Kuleva (1975) and Kochetkova (1970). Ostracode studies were performed by the author. Besides the original material, definitions by Kochetkova & Spirina (*in* Kuleva 1975) were used, in some cases provided with new strati-

FIG. 1. — The Upper Permian sections from the South-East of the Russian Plate and Cis-Ural marginal deflection. **P_2u**, Ufimian; **P_2kz_1**, Lower Kazanian; **P_2kz_2**, Upper Kazanian; **P_2t_1**, Lower Tatarian; **$P_2t_2^{sd}$**, Upper Tatarian (North Dvina horizon); **$P_2t_2^{vt}$**, Upper Tatarian (Vyatka horizon); **T_1**, Lower Triassic
1, Novo-Kandaurovka, the Chekushu - the Sukhalya River tributary (P_2u, P_2kz_1, P_2kz_2). **2**, Korneyevka, the Sukhalya River (P_2kz_2). **3**, Yurnaty, the Sukhalya River (P_2kz_1, P_2kz_2). **3a**, Taimasovo, the Bol. Kuyurgara River (P_2kz_1, P_2kz_2). **4**, Yalchikayevo, the Shaitanka River (P_2u, P_2kz_1). **5**, Well 104, Byelozyorka, the Salmysh River (P_2u, P_2kz_1, P_2kz_2). **6**, Karmalka, the Salmysh River (P_2kz_1, P_2kz_2). **7**, Well 124, Petrovka (P_2u, P_2kz_1, P_2kz_2, P_2t_1). **8**, Well 122, Verkhni Gumbet (P_2u, P_2kz_1, P_2kz_2, P_2t_1). **9**, Well 123, Voskresenskoye (P_2u, P_2kz_1, P_2kz_2, P_2t_1). **10**, Well 13[sh], the Shestimir River (P_2kz_2, P_2t_1). **11**, Well 12[vh], the Shestimir River (P_2u, P_2kz_1, P_2kz_2). **12**, Nizhni Babalar (P_2kz_1). **13**, Well 388, Yangiz (P_2u, P_2kz_1, P_2kz_2, P_2t_1). **14**, the Shestimir River (P_2kz_2, P_2t_1). **15**, Well 152[k], Maryevka, the Salmysh River (P_2u, P_2kz_1, P_2kz_2, P_2t_1). **16**, Well 157[k], Maryevka (P_2u, P_2kz_1, P_2kz_2). **17**, Brody Spring (P_2kz_2, P_2t_1). **18**, Well 3, Brody (P_2u, P_2kz_1). **19**, Well 43[k], Tiryak-Lizyak (P_2u, P_2kz_1, P_2kz_2). **20**, Well 48[k], (State farm) Oktyabrskij (P_2kz_2, P_2t_1). **21**, Well 55, Budyonnovskij (P_2t_1, $P_2t_2^{sd}$). **22**, Well 52[k], Anatolyevka, the Salmysh River (P_2u, P_2kz_1, P_2kz_2). **23**, Well 2[k], Sakmara (P_2u, P_2kz_1, P_2kz_2, P_2t_1). **24**, Well 1[k], Sakmara (P_2kz_1, P_2kz_2). **25**, Well 31[k], Grebeni (P_2kz_1, P_2kz_2, P_2t_1). **26**, Krasny Gully, Grebeni (P_2u, P_2kz_1, P_2kz_2, P_2t_1). **27**, Well 5[k], Grebeni (P_2u, P_2kz_1, P_2kz_2). **28**, Well 7[k], Grebeni (P_2kz_1, P_2kz_2). **29**, Well 39[k], Grebeni (P_2kz_1, P_2kz_2, P_2t_1). **30**, Well 6[k], Chebenki (P_2kz_2, P_2t_1). **31**, Well 30, Neznenka (P_2u, P_2kz_1, P_2kz_2, P_2t_1). **32**, Orenburg (P_2kz_1). **33**, Well 70[k], Bolshoj Sulak (P_2kz_1, P_2kz_2). **34**, Well 94[k], Bolshoj Sulak (P_2u, P_2kz_1, P_2kz_2, P_2t_1, $P_2t_2^{sd}$). **35**, Well 80, Dzhuan-Tyubinskaya (P_2kz_1, P_2kz_2, P_2t_1). **36**, Well 79[k], Dzhuan-Tyubinskaya (P_2u, P_2kz_1, P_2kz_2, P_2t_1, $P_2t_2^{sd}$, $P_2t_2^{vt}$). **37**, Well 98[k], Karavanny (P_2kz_1, T_1). **38**, Well 59[t], Boyevaya Mt. (P_2kz_2). **39**, Well 60[t], Boyevaya Mt. (P_2kz_1, P_2kz_2). **40**, Well 53[t], Boyevaya Mt. (P_2kz_2, P_2t_1). **41**, Wells 61[k]-67[k], Krasnoyarka (P_2kz_1, P_2kz_2, P_2t_1). **42**, Well 73[k], Kamennaya (P_2u, P_2kz_1, P_2kz_2, P_2t_1, $P_2t_2^{sd}$, $P_2t_2^{vt}$). **43**, Yeishanka ($P_2t_2^{vt}$, T_1). **44**, Korneyevka, the Yarykly River (P_2k_2). **45**, Yeldashevo, the Yurgashka River (P_2t_1). **46**, Skvorchikha, the Yergabusha River (P_2t_1). **47**, Osipovka, the Budenya (P_2kz_2). **48**, Karatalka, the Teiryuk River (P_2kz_2). **49**, Rodnikovsk, the Teiryuk River (P_2kz_2). **50**, Verkhotor, the Tor River (P_2kz_2). **51**, Voskresenskoye, the Tor River (P_2t_1). **52**, Vesyoly, the Nugush River (P_2t_1, $P_2t_2^{sd}$, $P_2t_2^{vt}$). **53**, Krasnogorka, the Nugush River ($P_2t_2^{vt}$). **54**, Lipovka (P_2t_1). **55**, Alexandrovka, the Nugush river (P_2kz_1, P_2kz_2, P_2t_1). **56**, Yumaguzino, the Meleuz ($P_2t_2^{vt}$, $P_2t_2^{vt}$). **57**, Kadyrovo, the Menyu River (P_2t_1). **58**, Malakanovo (P_2kz_1). **59**, Sergeyevskij, the Chukur - Bulyak River - the Bolshoj Yushatur tributary (P_2t_1). **60**, Chernigovskij ($P_2t_2^{sd}$). **61**, Bekechevo, the Nakuz River (P_2kz_1, P_2kz_2, P_2t_1). **62**, Savelyevskij ($P_2t_2^{vt}$). **63**, Sankinskij ($P_2t_2^{vt}$). **64**, Raznomoika, the Tugostemir River ($P_2t_2^{sd}$). **65**, Slavyanka (P_2kz_2, P_2t_1). **66**, Allaberdino (P_2kz_2). **67**, Davletkulovo, the Yaman-Yushatyr River (P_2kz_2, P_2t_1). **68**, Well 28 and well 43, Davletkulovo (P_2kz_1, P_2kz_2, P_2t_1). **69**, the Tashla River (P_2kz_2, P_2t_1). **70**, Alexandrovka, the Kuplya River ($P_2t_2^{sd}$). **71**, Urman-Tashla ($P_2t_2^{sd}$). **72**, Kasterinskij, the Bolshoi Yushatur River basin ($P_2t_2^{vt}$). **73**, Maslovskij, the Bolshoi Yushatur River basin ($P_2t_2^{vt}$). **74**, Smirnovka ($P_2t_2^{vt}$). **75**, Alebasirovaya ($P_2t_2^{vt}$). **76**, Cherepanovka, the Burunchar River ($P_2t_2^{vt}$). **77**, Well 41, Staroseika, the Bolshoi Ik River (P_2kz_1, P_2kz_2). **78**, Staroseika (P_2kz_2). **79**, Dmitriyevskij (P_2t_1, $P_2t_2^{sd}$). **80**, Well 4[t] and 5[t], Dmitriyevskij (P_2kz_2, P_2t_1, $P_2t_2^{sd}$). **81**, Stary Kaztair, the Chena River (P_2kz_2). **82**, Novosyolki, the Chena River (P_2t_1). **83**, Kholmogory, the Bolshoi Ik River (P_2t_1). **84**, Novokulchumovo, the Sakmara River ($P_2t_2^{sd}$, $P_2t_2^{vt}$). **85**, Well 121, Novokulchumovo (P_2kz_2, P_2t_1). **86**, Vyazovka, the Ural River ($P_2t_2^{sd}$, $P_2t_2^{vt}$). **87**, Well 102, Vyazovka, (P_2kz_2, P_2t_1) **88**, Well 19[k], Ostrovnoye, the Ural River (P_2kz_1, P_2kz_2, P_2t_1). **89**, Blumental Gully, the Burtya river ($P_2t_2^{vt}$, T_1). **90**, Zholloye, the Sakmara River (P_2kz_2). **91**, Giryal, the Ural River ($P_2t_2^{vt}$, $P_2t_2^{sd}$). **92**, Well 73, Activny (P_2kz_2, P_2t_1) **93**, Well 44, Verkhneozernoye, the Ural River (P_2kz_1). **94**, Verkhneozernoye (P_2kz_2, P_2t_1). **95**, Wells profile 5-22 the Burly River (P_2t_1, $P_2t_2^{sd}$, $P_2t_2^{vt}$).
a, outcrop exposure. **b**, well. **c**, boundary of the Cis-Ural marginal deflection. **d**, boundary of Peri-Caspian Depression. **A-B**, the line of the sections studied in Fig. 2. **C-D**, the line of the sections studied in Fig. 3. **E-F**, the line of the sections studied in Fig. 4.


56°
57°
SALAVAT
24km
Belaya
E
A
53°
Kumertau
C
Iugostemir
Nakyz
Bolshoij Yushatyr
Bolshoij Yik
Salmysh
Sakmara
52°
ORENBURG
Ural
B
D
F
Yelshanka
Sol-Iletsk
Akbulak
51°
55°
a
b
c
d
A-B - e
C-D - f
E-F - g

graphic interpretations.
Bivalve complexes were studied by Kuleva (1975), fish by Minikh & Minikh (*in* Ochev *et al.* 1979), conchostracans by Lopato (*in* Kuleva 1975), miospores by Shatkinskaya (Efremov & Shatkinskaya 1972). Tetrapod definitions belong to Tverdokhlebova, Chudinov & Ochev (*in* Ochev *et al.* 1979). The data on marine macrofauna was taken from the works by Kochetkova (1979) and Romanov (1972).
The wells were drilled by the Orenburg Territorial Geologic Service from 1960 to 1985.

UPPER PERMIAN DEPOSITS

The upper section of the Permian system in the south of the Cis-Ural marginal bend and the adjacent region of the Russian plate is represented by the Ufimian, Kazanian and Tatarian stages. The Kazanian and Tatarian stages are each represented by two substages: the lower and the upper ones. The lower substage of the Tatarian consists of the Urzhum horizon, the upper one of the North Dvina and Vyatka horizons.
According to the features of the Late Permian sedimentogenesis, this territory is divided (Fig. 1) into three structural-facial zones: the western (Novo, Kandaurovka, Grebeni and Yelshanka settlements), the axial (Raznomoika, Vyazovka, Blumental) and the eastern (Tor, Kholmogory, Burly). The principal stratigraphic units from each zone possess lithologic compositions, thicknesses and mineral complexes that differ to various extents (Figs 1-4).

THE UFIMIAN STAGE

The Ufimian stage from the western zone is studied in exposures and cores from numerous mapping and pioneer wells (Fig. 1, Kandaurovka, Shestimir, Yangiz, Urnyak, Brody, Sakmara, Grebeni, etc.).
The stage is composed predominantly of red terrigenous rocks that are replaced by halogenic Kungurian structures downwards along the section. The boundary between the Ufimian and Kungurian beds is conventionally drawn over the roof of the last more or less thick interlayer of chemogenic rocks. Clays, aleurolites, sandstones dominate in the section, marl, limestone and dolomite interlayers are rare. Rock gypsification is characteristically observed, significant in the lower portion (Fig. 2). The thickness varies from 75 to 190 m. Diverse organic remains occur: ostracodes, bivalves, conchostracans, miospores.
Ostracodes. *Paleodarwinula abunda* (Mandelstam), *P. angusta* (Mandelstam), *P. parphenovae* (Belousova), *P. procera* (Mandelstam), *P. lancetiformis* (Kashevarova), *P. trita* (Palant), *P. burjevoensis* (Palant), *P. lubimovae* (Kashevarova), *Garjainovula lija* (Spirina *et* Molostovskaya), *G. kulevae* (Spirina *et* Molostovskaya), *G. gracilis* (Spirina *et* Molostovskaya), *Prasuchonella stelmarta* (Kashevarova), *Pr. kargalensis* (Kotshetkova), *Pr. kamyschentaensis* (Palant), *Darwinuloides djurtjuliensis* Palant, *Sinusuella pergraphica* Mandelstam.
Bivalves. *Palaeomutela attenuata* Gusev, *P. ovataeformis* Gusev, *P. sintasensis* Gusev.
Conchostracans. *Hemicycloleaia baentschiana* (Beyrich), *Limnadia* (*Paleolimnadia*) *rossica* Molin.
Miospores. They are represented by two complexes: the early (Miospores H1) and the late ones (Miospores H2) (Efremov & Shatkinskaja 1972). Within the H1 miospore complex dominate *Zonotriletes*, significantly *Disaccites*, associated *Vittatina*, characteristic *Lycospora variabilis* (Jansonius), *Cirratriradites procumbens* (Luber), *Striatopodocarpites tajmensis* Sedova, *Striataidiplopinites elongatus* (Luber), *Vittatina striata* Luber, *Granisporites osmundae* (Samoilovich), *Granulatisporites resistens* (Luber), *Cirratriradites procumbens* (Luber), *Platysaccus alatus* (Luber), *Striatohaplopinites perfectus* (Naumova).
The Ufimian beds are poorly studied in the central zone due to little outcropping and the lack of core materials. A 180 m thick sequence of red gypsified clays, marls, sandstones with gypsum interlayers, situated a bit to the north of the area concerned, near the village of Yar-Bishkadak (Kotschetkova 1970), has been assigned to the Ufimian. The confirmed Ufimian beds to the south, were penetrated by well 79 in the left-bank region of the Ural River. They are represented by red clays, aleurolites and sandstones.

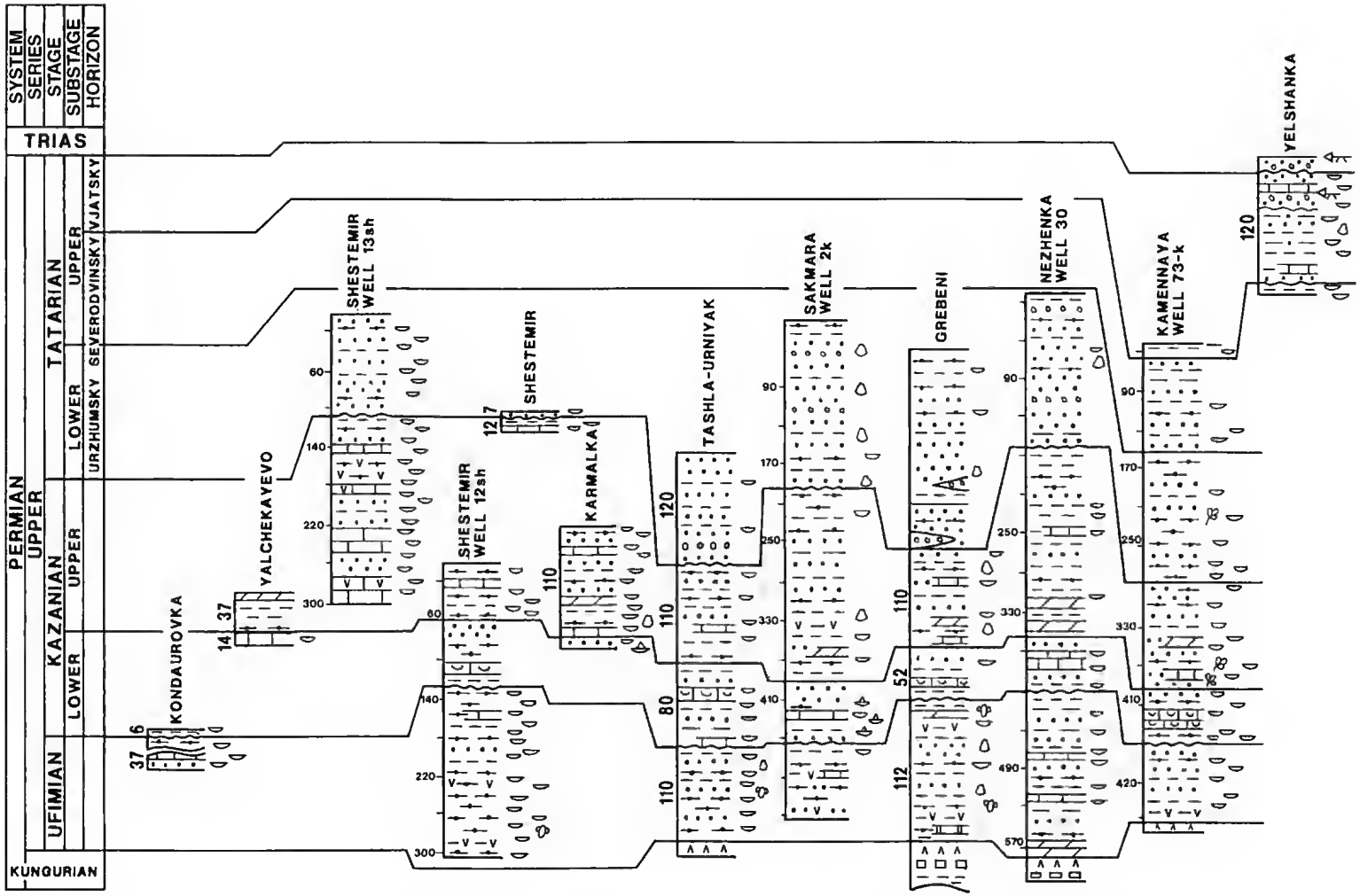


FIG. 2. — Correlations of the sections of the Upper Permian deposits in western part of the Cis-Ural marginal deflection (legend in figure 3).

Wells show the Ufimian beds to be up to 360 m thick. In the eastern zone, the Ufimian deposits occur along the Nugushu River (Vishnevskaya and Alexandrovka villages). They are represented by a thick (about 700 m) sequence of red conglomerates with flint pebbles, sandstones, aleurolites and marls with rare thin limestone interlayers. Coarse clastics are characteristic of the middle portion. Along the Nakyz river near the Ryazansky Farm and the basins of the Bolshoj Ik and Bolshoj Syuren Rivers, the Ufimian deposits are represented by thick pebble conglomerates often changed by boulder ones. These conglomerates consist of coarse pebbles of diverse metamorphosed and igneous rocks, limestones with Carboniferous faunal remains, quartz and flint. Sandstone lenses occur among conglomerates, and very seldom interlayers of marls and sulfur silicified limestone (Kotchetkova 1970).

In the vicinity of Zalair-Ilyinskoye and Starosejka villages, the Ufimian deposits are represented by 68 m thick reddish-brown argillites with interlayers of brownish-grey sandstones and grey limestones. The age of the sequence is established according to ostracode complex: the zonal guide fossil *Palendarwinula abunda* (Mandelstam) and *P. angusta* Mandelstam, *P. lancetiformis* Kashevarova, etc.

The Kazanian stage

The Kazanian stage according to its lithologic-facial features is divided into two substages: the lower and the upper ones.

The lower Kazanian stage

The lower Kazanian stage has a complicated structure within the area considered. In the west, it is represented by marine facies substituted by lagoonal-continental ones farther eastward, mainly in the axial zone; this reflects the transgressive-regressive cycle of the Kazanian sea (Fig. 1, Utnyak, Brody, Sakmara, Grebeni, Nezhenka, etc.).

Within the western zone, the lower Kazanian substage is composed of grey sandstones, aleurolites, clays and limestones. Clays and aleurolites dominate in the lowermost of the section; the middle part is represented mainly by limestones, marls and clays.

The upper third of the sequence is built of clays, aleurolites and sandstones, the latter ones often constituting up to 50-70% of its volume. The substage thickness varies from 60 to 200 m.

Diverse organic remains occur within the lower Kazanian deposits: ostracodes, corals, bryozoans, crinoids.

Ostracodes. Ostracodes are represented by the marine species: the guide fossil *Amphissites tscherdynzevi* Posner and *Pseudoparaparchites formidabilis* Schneider, *Accuminella bella* Khivintseva, *Cornigella valosa* Khivintseva, *Kirkbya rara* Khivintseva, *Moorea facilis* Schneider, *Cavellina grandis* Schneider, *Cavellina unica* Kotschetkova, *Healdia postcornuta* Schneider, *H. oblonga* Kotschetkova, *Healdia simplex* Roundy, *H. pseudisimplex* Kotschetkova, *H. subtriangula* Kotschetkova, *H. reniformis* Schneider, *Healdianella vulgata* Kotschetkova, *Cribroconcha urschakensis* Kotschetkova, *Bairdia beedei* Ulrich *et* Bassler, *B. garrisonensis* Upson, *B. pompilioides* Harlton, *Acratia baschkirica* Kotschetkova, *Fabalicypris crepidalis* Kotschetkova, *Actuaria diffusa* Schneider, *A. secunda* Kotschetkova, *Monoceratina fastigiata* Kotschetkova, *M. faveolata* Kotschetkova, *M. parvula* Kotschetkova, *M. exilis* Schneider, *Fascianella notabilis* Schneider.

Foraminifers. *Glomospira* sp., *Ammodiscus* cf. *bradynus* Pandel, *Verneuilinoides kasanica* Ucharskaya, *Cornuspira megasphaerica* Gerke, *C. microsphaerica* K. M. Maclay, *Calcivertella kasanica* K. M. Maclay, *Nodosaria cushmani* Paalzov, *N. forcimeniformis* K. M. Maclay, *N. hexagona* (Tscherdynzev), *N.* aff. *noinskyi* Tscherdynzev, *N. krotovi* Tscherdynzev, *Pseudonodosaria lata* K. M. Maclay, *Frondicularia longissima* (K. M. Maclay), *Fr. geinitzinaeformis* (K. M. Maclay), *Geinitzina spandeli* Tscherdynzev, *Tetrataxis* sp., *Tristis permiana* Gerke, etc.

Brachiopods. *Cleiothyridina pectinifera* Sowerby, *Cl. semiconcava* Waagen, *Cl. reyssiana* Keyserling, *Stepanoviella hemisphaerium* Kutorga, *Pr.* (*Cancrinella*) *cancrini* Verneuil, *Pr. koninckianus* Keyserling, *Licharewia rugulatia* Kutorga, *L. curvirostris* Verneuil, *Dielasma elongata* Schlotheim, *D. elliptica* Netschajev, *D. angusta* Netschajev, *Lingula orientalis* Golowkinsky, *Aulosteges horrescens* Verneuil.

Bivalves. *Leibea hausmanni* Goldfuss, *Allorisma*

elegans King, *Pseudobakewellia sulcata* (Geinitz), *Ps. ceratophragaeformis* Noinski, *S. tutchburia tschernyschevi* Licharev.

In the central and eastern zones, the lower Kazanian comprises a sequence of grey-colored sandstones, aleurolites, clays, marls, limestones and dolomites of lagoonal-deltaic and littoral-marine genesis (Figs 1, 2, 3, Davletkulovo, Bekeshevo, Starosejka, Ostrovnoye, Verkhneozernoye). The sequence contains the Kazanian complex of non-marine ostracodes: guide zonal fossil *Paleodarwinula fainae* (Belousova) and *P. cuneata* (Kotschetkova), *P. irinae* (Belousova), *Prasuchonella belebeica* (Belousova), *Darwinuloides* cf. *sentjakensis* (Sharapova).

Non-marine bivalves. *Paleomutela sintasensis* Gusev, *P. ovataeformis* Gusev, characteristic of the Ufimian and Lower Kazanian deposits.

Flora. *Pecopteris anthriscifolia* Meyen, *Sphenophyllum*, *Asterodiscus*.

Pollen of cordaites: *Cordaitina uralensis* (Luber) Samoilovich, *C. eubrotata* (Luber) Samoilovich.

Ginkgos: *Ginkgocycadophytus erosus* (Luber) Samoilovich.

Conifers: *Protodiploxypinus elongatus* Samoilovich, *Protopodocarpus alatus* Samoilovich.

Some pollen of obscure systematic affiliation: *Azonalites* (*Rugosina*) *tenuis* Luber, *A.* (*Tenuella*) *levis* Luber.

Fern-like spores: *Azonotriletes* cf. *resistens* Luber, *A. osmundes* Samoilovich (Kuleva 1975).

The upper Kazanian substage

The upper Kazanian substage in the western zone is represented by lagoonal-continental formations: red, less frequently grey clays, aleurolites, sandstones, and, to a smaller extenr, by limestones, marls, dolomites (Yalchekayevo, the Shestemir River, Shestemir, the Karmalka Spring, Tashla-Urnyak, Sakmara, Grebeni, Nezhenka, etc.). The lower boundary of the late Kazanian deposits is clear, drawn over the roof of marine sandstones, overlain by clays with the zonal guide fossil *Paleodarwinula fainae* (Belousova). Its thickness varies from 110 to 140 m.

Within the axial zone (Davletkulovo, Slavyanka, Islayevka, Ostrovnoye), the upper Kazanian substage is composed of non-marine interlaid clays, aleurolites and sandstones with rare interlayers of limestones and marls. Within the section near Davletkulovo village, scattered small flint and marl pebbles occur as well as small lenses of fine-pebble conglomerates. The substage is up to 600 m thick there. The section near Ostrovnoye village is distinguished for thiner rocks; it is 250 m thick.

The upper Kazanian substage has a somewhat uneven structure in the eastern zone. At the Tor River (Kotchetkova 1970), this is represented by a thick (556 m) carbonate-terrigenous sequence composed of interlaid brown, lilac and grey clays, aleurolites, marls, limestones, sandstones. The Kazanian is not divided into substages within the section along the Nugush River. Assigned to it is a thick (over 700 m) sequence of brown, lilac, grey marls and aleurolites with sandstone interlayers; this sequence overlies a sand-conglomerate one, that is conventionally considered to belong to the Ufimian stage. Coarse clastics are rather significant near Zhyoltoye village: sandstones, gravelstones and conglomerates. The section near Novokulchimovo is represented by a rather monotonous interlayers of concretionary and bedded brown limestones. Diverse organic remains occur within the upper Kazanian deposits over the whole of the territory: ostracodes, bivalves, conchostracans, tetrapods, flora and miospores.

Ostracodes. Ostracodes are represented by the following species: *Paleodarwinula fainae* (Belousova), *P. alexandrinae* (Belousova), *P. irenae* (Belousova), *P. cuneata* (Kotschetkova), *P. tichonovichi* (Belousova), *P. tuimazensis* (Kotschetkova), *P. varsanofievae* (Belousova), *P. inornatinaeformis* (Belousova), *P. chramovella* (Belousova), *P. aronowae* (Belousova), *P. persimplex* Kotschetkova, *P. procurva* (Kotschetkova), *Garjainowula lija* (Spirina *et* Molostovskaja), *G.* ex gr. *gracilis* (Spirina *et* Molostovskaja), *Prasuchonella tichwinskaja* (Belousova), *P. belebeica* (Belousova), *Darwinuloides sentjakensis* (Scharapova), *Placidea* ex gr. *lutkevichi* (Spizharskyi). *Schneideria kazanica* Kotschetkova occurs only in the lower part of the section.

Bivalves. Bivalves are represented by the Belebej complex : *Palaeanodonta rhomboidea* (Netschaev), *Palaemutela celebrata* Gusev, *P. quadrata* Kuleva, *P. novalis* Netschaev, *P. umbonata*

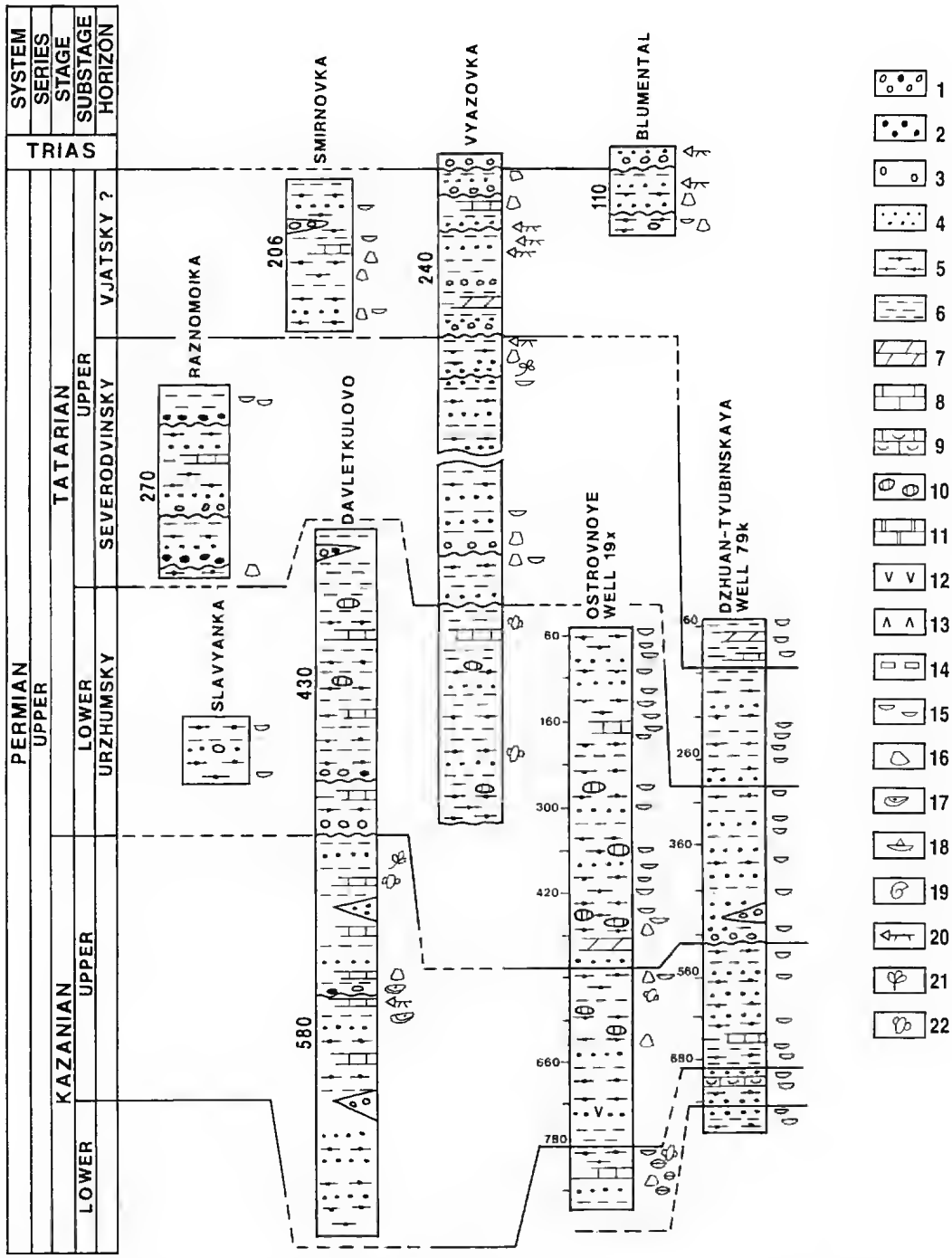


FIG. 3. — Correlations of the sections of the Upper Permian deposits in central part of Cis-Ural marginal deflection. **1**, conglomerates. **2**, Ural rocks pebbles. **3**, local rocks pebbles. **4**, sandstones. **5**, aleurolites (siltstones). **6**, clays. **7**, marls. **8**, limestones. **9**, organogenic-clastic limestones. **10**, nodular limestones. **11**, dolomites. **12**, gypsum. **13**, anhydrites. **14**, salts. **15**, ostracodes. **16**, bivalves. **17**, conchostraceans. **18**, brachiopods. **19**, foraminifers. **20**, gasteropods. **21**, tetrapods. **22**, fishes. **23**, flora. **24**, miospores.

(Fischer); *P. krotovi* Netschaev, *P. olgae* Gusev, *P. doratiformis* Gusev.

Conchostracans. *Palaeolimnadiopsis eichwaldi* (Netschaev), *Clyptoasmussia exiqua* (Eichwald), *Cyclotungusites kazanensis* Molin, *Ulugkemia borisi* Novojilov, *U. orengurgiana* Molin, *U. petri* Novojilov, *Sphaerestheria ikensis* Molin, *Pseudestheria kaslanica* Molin.

Tetrapods. *Platyaps* sp., *Deuterosaurus* sp., *Tapinocephalidae*, similar in dimensions to *Deuterosaurus gigas* Efremov.

Miospores. Characteristic *Cordaitina*, *Limitisporites leschikii* Klaus, *Gigantosporites hallstathensis* Klaus, *Striatites marginalis* Klaus, *Striatohaplopinites latissimus* (Luber), *Striatopiceites suchinensis* Sedová, *Vittatina striata* Luber, associated *Cyclogranisporites*, *Acanthotriletes*, *Azonaletes*.

Flora. *Carpolithes* sp., *Phyllododerma* sp., *Noeggerathiopsis* sp., *Lepeophyllum* sp., *Samaropsis* sp., *Paracalamites* sp., *Odontopteris* sp., *Equisetina* sp., *Rufloria* sp., *Taeniopteris* sp., *Recopteris* sp., *Voltzia mamadyschensis* Zalessky, *Samaropsis irregularis* Neuburg, *Psygmophylum expansum* Brongniart, *Odontopteris* cf. *rossica* Zalessky, *Ullmannia biarmica* Eichwald.

The Tatarian stage

The Urzhum horizon

The lower Tatarian substage (Urzhumsky in figures 2-4) in the western zone discontinuously overlies the Kazanian beds and is characterized by binary structure (Shestemir, Sakmara, Grebeni, Nezhenka, Boyevaya Mt.). Its lower part is composed of obliquely layered red sandstones, aleurolites, clays and fine-pebble conglomerates of local-rock pebbles. The upper half is built of red aleurolites, clays, fine and more seldom coarse-grained sandstones. The horizon is up to 200 m thick.

This division in two parts becomes progressively less vivid eastwards (Kamennaya, Dzhuan-Tyubinskaya).

The axial zone of the Urzhum horizon is distinguished for high thicknesses, aleurolite-clayey composition, conglomerate-lens occurrence and widely spread nodular limestones. The number of conglomerate interlayers reduces southwards (Fig. 3), the number of nodular limestones increases. The section near Davlerkulovo village is composed of red interlaid clays and aleurolites, sandstone, limestone and marl interlayers, thin lenticular interlayers of fine-pebble conglomerates and gravelstones with their clastics consisting mainly of flints. Unevenly scattered flint pebbles and gravels occur in some aleurolite interlayers. A thick (6 m) interlayer of coarse-pebble conglomerate lies in the base of the section. The boundary between the Kazanian and Tatarian deposits is drawn over its rugged lower surface. The apparent thickness - 430 m. The Urzhum horizon section near the villages of Ostrovnoye and Vyazovka looks more monotonous and consists of finer rocks. It is over 550 m thick. The Urzhum horizon is unevenly structured within the eastern zone (Fig. 4). It is characterized by binary structure in the north of the zone, in the sections along the Tor, Yergabusha and Yurgashi rivers. Its lower half consists of a conglomerate-sandstone sequence with rare interlayers of red-brown clays and marls. The upper one is represented by a marl-clay-sandstone sequence with interlayers of grey clayey limestones and aleurolites. The horizon is 780 m thick.

Southwards, near the villages of Bekechevo, Dmitriyevo, Kholmogory, the Urzhum horizon is dominated by interlaid clays, aleurolites, interlayers of fine-grained sandstones and brown concretionary limestones. Fine and coarse-pebble and even boulder conglomerates are also important. Their clastic material is poorly sorted. The pebble sizes vary from 1 to 10 cm, the boulders are up to 20-25 across. Large pebbles and boulders are represented by the Lower Permian and Middle Carboniferous limestones and sandstones; fine pebbles by flints. Conglomerates are usually found within the bases of sedimentation rhythms which are closed by clays with nodular limestones. Conglomerate members in the lower part of the section are up to 8-10 m thick. Upwards along the section, conglomerate members become thinner and the sizes of clastic materials decrease (Kuleva 1975).

Farther south, towards the Peri-Caspian Depression (Burly), and to the west of the Urals forefolds (Novokulchumovo), the sizes of clastic material and the share of coarse-clastic rocks in the section decrease. The principal position in its

structure is occupied by clays, aleurolites and fine-grained sandstones. The following features are characteristic of these sections: rather monotonous brown color of the rocks, scattered limestone nodules, aleurolite predominance within the lower part of the section and that of clays in its upper part. The apparent thickness of the Urzhum horizon section at Burly constitutes 960 m.

Ostracodes. The paleontologic description of the Urzhum horizon is complete and involves large variety of forms. Ostracodes are represented by a rich complex consisting of the following species: zonal guide fossil *Paleodarwinula fragiliformis* (Kashevarova) and *P. elongata* (Lunjak), *P. fragilis* var. *augusta* (Schneider), *P. inornatinae* (Lunjak), *P. chramovi* (Glebovskaya), *P. torensis* (Kotschetkova), *P. faba* (Mischina), *P. impostor* (Mischina), *P. defluxa* (Mischina), *P. arida* (Molostovskaya), *P. obvia* (Molostovskaya), *P. garianovi* (Molostovskaya), *Prasuchonella nasalis* (Sharapova), *Darwinuloides buguruslanicus* Kashevarova, *Sinusuella ignota* Spizharskyi, *Placidea lutkevichi* (Spizharskyi).

All the species listed above are rather widely distributed within the Urzhum horizon rocks over the whole of the Russian Platform (Molostovsky & Molostovskaya 1967; Molostovskaya 1974, 1993). Besides, the upper part of the Urzhum horizon in the territory considered is characterized by isolated localities of endemic cytherides: *Tscherdynzeviana squamosa* Kotschetkova, *Wetluginella* (?) *tatarica* Molostovskaya in press, *Kaschevaroviana delicata* Molostovskaya in press, *K. pectunata* Molostovskaya in press.

Bivalves. *Abiella subovata* (Jones), *Microdantella microdonta* (Khalfin), *M. plotnikovskiensis* (Fedotov), *Palaemutela doratiformis* Gusev, *P. parallelogramma* Kuleva, *P. gusevi* Kileva, *Anthraconaia verneuili* (Amalizky), *A. aktubensis* Gusev, *Anthraconauta* (*Prokopievskia*) *pseudophillipsi* Fedotov.

Conchostracans. *Pseudostheria angulata* (Lutkevich), *Sphaerestheria belorussica* Novojilov, *Triedrolophus tverdochlebovi* Molin, *Pseudostheria otchevi* Molin, *Megasitum jaroslavlense* Novojilov.

Tetrapods. *Mnemeiosaurus jubilaevi* Novikov, *Melosaurus* sp., *Deuterosaurus* sp., *Platyops* sp., *Notosyodon* sp.

Miospores. Characteristic *Lebachiacites pulcherrimus* (Sauer), *Striatoleachites*, *Jugasporites*, *Faunipollenites*, *Jaeniasporites albertal* Jansonis, *Vittatina striata* Luber; associated *Platysaccus* sp., *Alisporites striatohaplopinites*.

The North Dvina horizon

The North Dvina horizon (Severodvinsky in Figs 2-4) in the western zone is represented by interlaid red clays, aleurolites, sandstones, rare lenses of fine-pebble conglomerates of mostly local rocks and isolated interlayers of brown clayey limestones (Budyonovsky, Ostrovnoye, Kamenny).

As in the western zone, the North Dvina horizon section in the south of the central zone is characterized by rather fine terrigenous composition and red rock-color (well 73^{k} Dzhuan-Tyubinskaya, Vyazovka).

The North Dvina horizon is ununiform in its structure in the north of the central zone and in the eastern zone. It is variegated and characterized by carbonate-clayey composition, being formed of redrown, lilac, grey clays, aleurolites, sandstones, limestones and marls. The interlayers of grey rocks generally contain large amounts of charred plant detritus (Gumaguzino, Vesyoly, Raznomoika, Chernigovsky, Alexandrovka on the Kuplya River, Uman-Tashla, Dmitrovsky, Novokulchumovo, Giryal, Burly). In some sections (Chernigovsky, Raznomoika, Dmitriyevsky), coarse clastics (sandstones and conglomerates) are rather significant in the horizon structure. They are generally associated with the lower half of the section, sometimes forming a sequence up to 300 m thick there (Chernigovsky). The amount of coarse terrigenous material within the North Dvina horizon decreases westwards and southwards from the Urals to the Peri-Caspian Depression. The number of grey-rock interlayers decreases in the same direction.

The thickness of the North Dvina horizon varies from 100 m (Ostrovnoye) to 670 m (Burly).

The rock ages within the North Dvina horizon are determined by numerous and multiform organic remains.

Ostracodes. Ostracodes are represented by rich and diverse associations. The following species are ubiquitous: zonal guide fossil *Suchonellina futschiki* (Kashevarova) and *S. inornata* Spizhar-

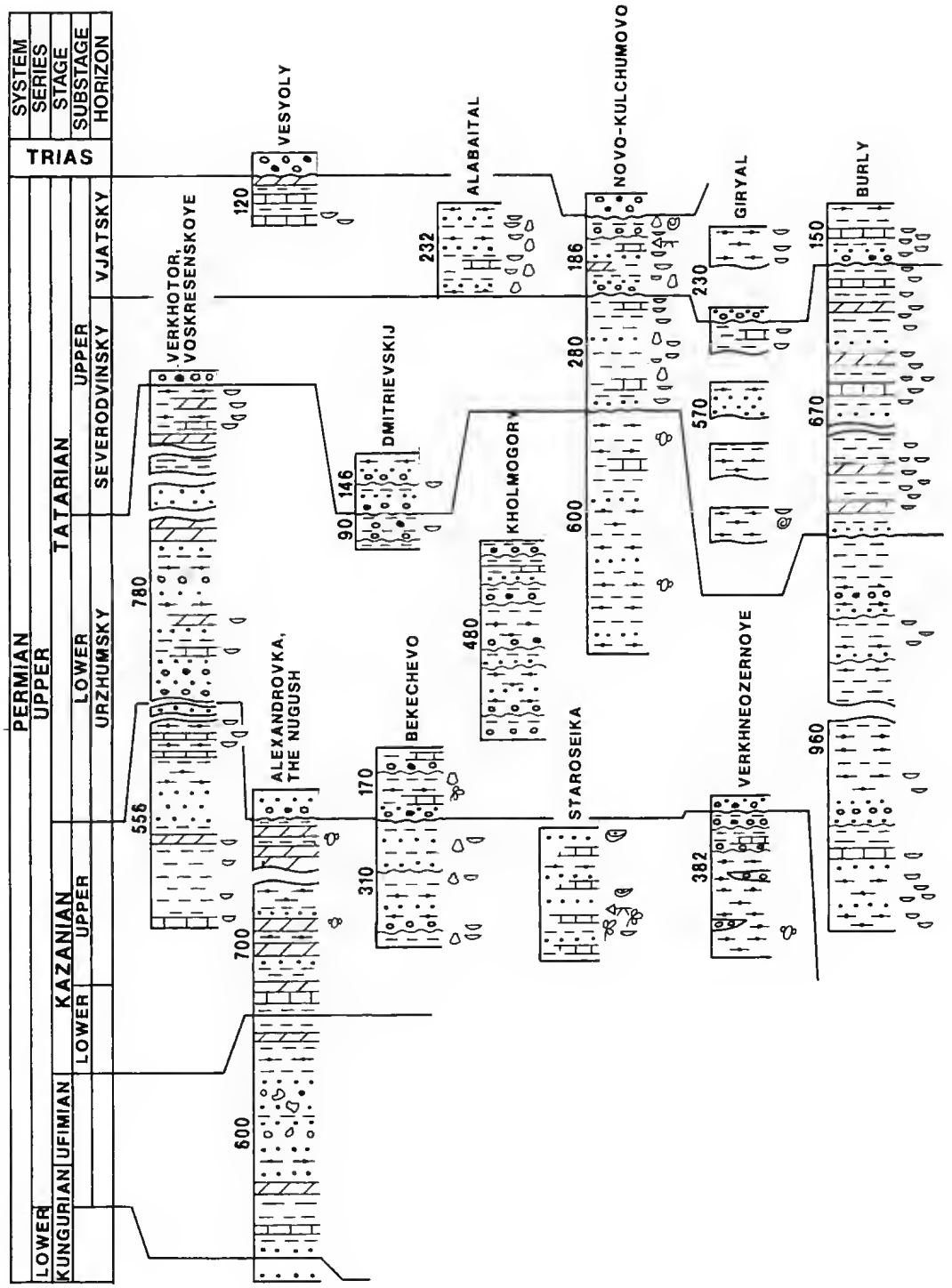


FIG. 4. — Correlations of the sections of the Upper Permian deposits in eastern part of Cis-Ural marginal deflection (legend, see figure 3).

skyi, *S. parallela* Spizharskyi, *S. undulata* (Mishina), *S. daedala* (Mishina), *S. cultella* (Mishina), *S. degitalis* (Mishina), *S. spizharskyi* (Pozner), *Prasuchonella stelmachovi* (Spizharskyi), *P. sulacensis* (Starozhilova), *Darwinuloides buguruslanicus* Kashevarova, *Permiana elongata* Posner, *P. oblonga* Posner, *Tscherdynzeviana pylchra* Belousova, *T. buzulukensis* Kashevarova.

Besides the ostracode listed above, some peculiar sculptured endemic cytherides occur in the eastern zone : *Tscherdynzeviana busulucensis* Kashevarova, *T. pennata* Kotschetkova, *T. abscondita* Kotschetkova, *Netschajewiana costata* Kotschetkova, *Nuguschia sinizyni* Kotschetkova, *Kaschevaroviana delicata* Molostovskaya in press, *K. pectinata* Molostovskaya in press, *Jungunulus mirus* Molostovskaya in press, *Permianella inilaterata* Molostovskaya in press, *Pamilio primaris* Molostovskaya in press. They are clearly different from those common for the Russian Platform in their morphologic features, being close to marine and semimarine cytherides of the Triassic from the Peri-Caspian Depression.

Bivalves. Bivalves are represented by *Palaeomutela inostranzevi* Amalizky, *P. keyserlingi* Amalizky, *Palaenodonta fischeri* Amalizky, *Opokiella ignatjevi* Gusev.

Conchostracans. *Siberioleaia oblonga* (Mitschell), *Hemicycloleaia intermediata* (Mitschell), *Pseudostheria cicatricosa* (Novojilov).

Tetrapods. *Chroniosaurus dongusensis* Tverdochlebova, *Rophanodon tverdochlebovae* Ivachnenko, *Microphon exiguus* Ivachnenko.

Fishes. *Isadia aristoviensis* A. Minich, *I. suchonensis* A. Minich, *Toyemia tverdochlebovi* Minich.

Flora. *Pursongia amalitzkii* Zalessky, *Cordaites clercii* Zalessky.

Miospores. *Limitisporites* sp., *Jugasporites* sp., *Lueckisporites virkkiae* Potonie *et* Kremp, *Taeniaesporites albertae* Jansonius.

The Vyatka horizon

The Vyatka horizon (Vyatsky in Figs 2-4) in the western and central zones, like the North Dvina one, is composed of terrigenous and mostly red rocks: clays, aleurolites and, to a smaller extent, sandstones. Rare thin conglomerate interlayers or lenses occur, with their clastic material represented by local-rock pebbles, more seldom by flints and quartz (Savelyevka, Sankinsky, Kasterinsky, Maslovsky, Ostrovnoye, Dzhuan-Tyubinskaya, Kamennaya, Yelshanka, Vyazovka, Blumental). Grey and greenish-grey conglomerates and sandstones in Blumental Gully are associated with copperore manifestations. All the rock there are characterized by large amounts of charred plant remains: equisetite stem fragments, pieces of silicified wood.

The Vyatka horizon sections in the eastern zones are dominated by brown and, more seldom, grey clays, aleurolites, sandstones. Grey, lilac, brown limestones and marls are also important. Some conglomerates occur, fotming rather large lenses and interlayers. Their clastic material is represented by flints, quartz, limestones, effusive rocks and more seldom, local red rock (Vesyoly, Krasnogorka, Yumaguzino, Smirnovka, Alebastrovaya, Cherepanovka, Novokulchu-movo, Giryal, Burly). The thickness of the Vyatka horizon comprise 245 m near Novokulchumovo, 465 m near Vyazovka.

The rocks from the Vyatka horizon contain diverse organic remains.

Ostracodes. Ostracodes are represented by the following species: guide fossil *Suchonellina trapezoidea* (Sharapova) and *S. parallela* Spizharskyi, *S. undulata* (Mishina), *Wjatkellina fragilina* (Belousova), *W. fragilis* (Schneider), *W. vladimirina* (Belousova), *Dvinella* ex gr. *cyrta* (Zekina), *Suchonella typica* Spizharskyi, *Tatariella angulata* Mishina, *Placidea lutkevichi* (Spizharskyi), *Tscherdynzeviana pulchra* (Belousova).

Besides them, the sections from the eastern zone bear endemic sculptured cytherides, conveyed from the North Dvina horizon *Tscherdynzeviana pennata* Kotschetkova, *Netschajewiana costata* Kotschetkova, *Kashevaroviana delicata* Molostovskaya in press, *Pamilio primaris* Molostovskaya in press.

Bivalves. *Palaeomutela inostranzevi* Amalizky, *P. orthodonta* Amalizky, *P. ovalis* Amalizky, *P. plana* Amalizky, *Palaeanodonta fisheri* Amalizky, *P. okensis* Amalizky, *Opokiella tschernyschevi* Plotnikov.

Conchostracans. *Limnadia angulidorsa* Novojilov, *L. maitschatica* Novojilov, *L.* (*Falsisca*) *furaica* Novojilov, *Megasitum kaljugense* Novojilov, *M. vanum* Novojilov.

Tetrapods. *Chroniosuchus uralensis* Tverdoch-

lebova, *Kotlassia* sp., *Raphanodon* sp., *Scutosaurus* sp., *Inostrancevia uralensis* Tatarinov, *Scylacosuchus orenburgensis* Tatarinov, *Dicynodon* cf. *amalitzkii* Suschkin.

Fishes. *Isadia aristoviensis* A. Minich, *Wodnika invicta* A. Minich.

SUMMARY

All the Upper Permian stratigraphic units from the southern Cis-Urals are at present provided with reasonably complete paleontologic description. Their detailed division was carried out according to ostracode fauna. The red beds of the Ufimian stage are characterized by a non-marine ostracode complex dominated by representatives of *Paleodarwinula* genus. Within the sections with the Kazanian marine and continental deposits, the marine-rock sequences are characterized by rich marine-ostracode complexes of *Healdia*, *Bairdia*, *Amphissites*, etc., genera. The non-marine Kazanian deposits contain a single complex of non-marine ostracodes, mainly of *Paleodarwinula* and *Darwinuloides* genera.

The most detailed stage division by ostracodes was carried out for the Tatarian, with the Urzhum, North Dvina and Vyatka horizons clearly distinguished by the ratios of certain species and genera. The Urzhum horizon is defined by the combination of *Paleodarwinula* species and abundant *Prasuchonella*; the North Dvina one by domination of *Suchonellina* and *Prasuchanella*, the Vyatkian horizon by origination of new genera: *Wjatkellina*, *Dvinella* and *Suchonella*.

The peculiarities of ostracode complex distributions revealed in the Cis-Ural Deflection, are sustained all over the Russian Plate (Molostovskaya 1993) for detailed correlations within vast territories from the boreal regions to the northern fringes of the Tethys.

The presence of peculiar endemic cytherid complex in the south-east of Cis-Ural Marginal Deflection may point to a possible link between this territory and the Tethys marine plain in the Tatarian age.

Thorough search for ostracodes in other regions should be considered a primary task aimed to distant correlations.

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Depositional conditions in the southern Cis-Urals basin during Late Permian (biostratigraphic, lithofacies and petromagnetic data)

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ABSTRACT

This paper contains the results of the analysis of the Late Permian depositional environments in the southern Cis-Urals. The work is based on the data of several terms of reference sections. Thicknesses, facies and organic remains contens of the sediments were studied showing the regional stratigraphic boundaries caused by events of geologic and geographic history of the region. The main events of the geologic history were connected with the developmental pecularity of three contacted tectonic structures, *i.e.* the Ural Mountains, the marginal part of the Russian platform and the Peri-Caspian Depression.

KEY WORDS
Upper Permian,
Cis-Urals,
Russian Platform,
Peri-Caspian Depression,
biostratigraphy,
petromagnetism,
paleogeography.

RÉSUMÉ

Les résultats de l'analyse des paléoenvironnements de dépôts dans le sud du Cis-Oural au Permien supérieur sont présentés ici. Ce travail est fondé sur les données de plusieurs dizaines de coupes de références. Les épaisseurs, faciès et contenu paléontologique mettent en évidence des limites correspondant à des événements de l'histoire géologique et géographique de la région. Les principaux événements sont en connexion avec le développement des trois grandes unités tecroniques encadrant la région : l'Oural, la bordure de la Plate-forme Russe et la Dépression Peri-Caspienne.

MOTS CLÉS
Permien supérieur,
Cis-Oural,
Plate-forme Russe,
Dépression Peri-Caspienne,
biostratigraphie,
pétromagnétisme,
paléogéographie.

INTRODUCTION

The South Cis-Ural Region, embracing several northern districts of Orenburg region and a part of south-western Bashkiria, occupies an area of about forty thousand square kilometers within 51°53'30"N and 55-57°E. This rectangular territorial detachment is limited by the Ural Mountains to the east and the Salmysh River valley to the west, its northern boundary is conventionally drawn along the Salavat latitude, and the southern one along the Sol-Iletsk latitude.

The region is of special geological interest, since it represents a complicated tectonic junction, a meeting point of several major structures: the south-eastern fringe of the Russian Platform, the Cis-Ural Marginal Deflection, the Uralfolds area and the Peri-Caspian Depression (Fig. 1).

The morpho-tectonic structure of the region developed and took shape in the Late Permian, in the process of the Ural geosyncline closure at the final stages of the Hercynian tectonic cycle. Active orogeny in the Ural Mountains zone, inception of the Cis-Ural Marginal Deflection, epi-orogenic oscillations at the edge of the Russian Plate and an extensive transgression of the boreal Kazanian sea, have determined the succession of the Late Permian paleogeographic events not only for the South Cis-Urals but for the adjacent areas of the Tethys northern fringes as well.

The major part of the territory described is occupied by the Cis-Ural Marginal Deflection filled with the Upper Permian and Lower Triassic red-bed deposits with the underlying Kungurian sequence. The southern part of the Deflection, between the Bashkir Arch and the Peri-Caspian Depression, is known under the name of the Belskaya Depression; its eastern border is marked by the front ridge of the Ural Mountains and the western one is established by the steep sinking of the Kungurian salt-complex roof. The last phenomenon is clearly recorded by the sub-southern zone of isohypse closeness in the reference electric horizon (Mavrin 1970, 1979).

The Cis-Ural Marginal Deflection within the territory considered may be divided into the western, central and eastern zones according to the structural-facies features of the Upper Permian red-bed molasse. The boundaries of the structural-facial zones are indicated by two sub-southern belts of linear rises of the Kungurian halogenic sequence marked by salt-dome chains (Fig. 1).

RESEARCH SUBJECT

The paper deals with analyses of Late Permian

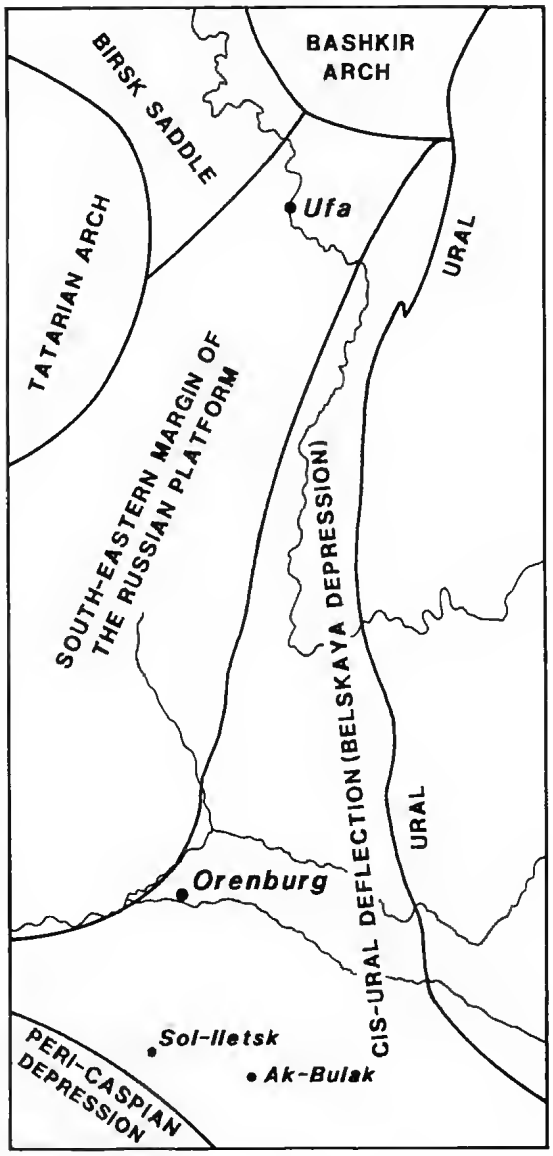


Fig. 1. — Main structural elements of the southern Cis-Ural.

depositional settings in the South Cis-Ural region. The research is based on the materials collected by the authors in the process of geological surveying and thematic paleomagnetic and biostratigraphic studies (Molostovsky & Molostovskaya 1967; Molostovskaya 1974, 1985, 1993). It summarises the original data on several tens of reference sections and wells, and the materials of Kotschetkova (1970), Kuleva (1975, 1979), Tverdokhlebov (Kuleva & Tverdokhlebov 1974), Forsh (1955).

Beside lithofacies and paleontological data, the paleogeographic reconstructions involved the use of measurements of scalar magnetic rock characteristics: natural remnant magnetism (Jn) and magnetic susceptibility (æ). The fundamentals of magnetometric data interpretation are presented in detail elsewhere (Molostovsky 1969, 1986); in essence, the levels of rock magnetisation are controlled mainly by ferromagnetic mineral concentrations. Sedimentary sequence saturation with terrigenous magnetic material is directly related to the paleogeographic conditions of sedimentogenesis and with the geodynamic settings in the source land provinces. In the peculiar settings of the South Cis-Urals, magnetic parameters proved to be a sensitive indicator of the principal Late Permian tectonic speeding up of the folded Urals, since the Paleozoic volcanogenic sequences of the Trans-Urals provided the main magnetic-material input to the Cis-Ural Deflection (Molostovsky 1969).

SEDIMENTATION CYCLES IN THE LATE PERMIAN

Five sedimentation cycles are quite distinct in the Late Permian history of the South Cis-Urals: the Ufimian, Early Kazanian, Late Kazanian, Early and Late Tatarian ones. Each of them was caused by major tectonic and landscape-climatic changes, recorded in the lithofacies, paleontological and petromagnetic characteristics of the Upper Permian formation complex.

THE UFIMIAN SEDIMENTATION CYCLE

The first stages of the Late Permian sedimentogenesis coincided with the Kungurian saliferous basin extinction, related to tectonic movement speeding up within the folded Urals zone and with the input of significant amounts of fresh water and terrigenous materials.

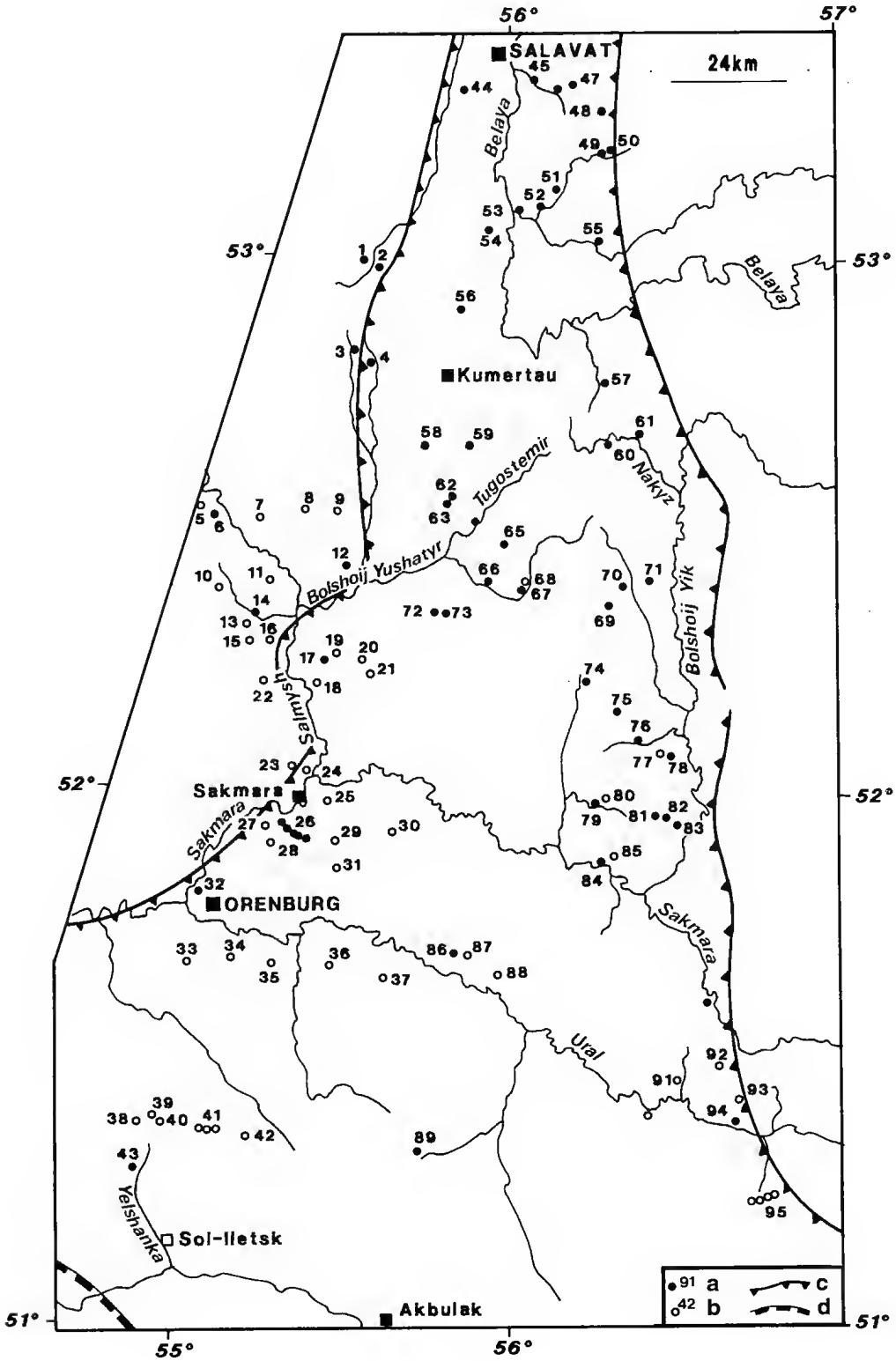
Strong magnetisation of the Ufimian deposits in the eastern zone of the marginal deflection indicates that denudation has affected the Paleozoic volcanites in the eastern zone of the folded Urals, and that the Belskaya Depression existed as a negative morphostructure as early as in the beginning of the Late Permian.

In the platform part of the South Cis-Urals, the Early Ufimian sedimentation took place under the conditions of a shallow residual basin with an unstable salt regime. In the Orenburg district, within the zone of the Salmysh rises, accumulation of red-bed siltites and sandstones started, alternating with evaporites-gypsums, dolomites, dolomitised marls and limestones.

As the post-Kungurian reservoir was gradually freshening, and the lacustrine-alluvial plain was being formed, the Orenburg Cis-Urals have become the area for terrigenous continental sedimentation which brought about a red-bed silt-sandstone sequence about 100-150 m thick. The principal structure peculiarities of the southern type Ufimian section are recorded in numerous outcrops and wells.

To the north of the region considered, within the Bashkir Cis-Urals, saliferous basin relicts were preserved in the first stages of the Ufimian sedimentation cycle. Dolomites, dolomitised limestones, gypsums and anhydrites were still accumulating intensively enough; their grey-coloured sequence is recognised as the Solikamsk horizon (Kochetkova 1970). In the second half of the Ufimian age, the paleogeographic setting was gradually adjusting and the red-bed Sheshma horizon from southern Bashkiria is identical to the corresponding deposits from the Orenburg Cis-Urals in its lithofacies features.

Aquatic biota is represented by non-marine ostracodes, bivalves and rare conchostracans. The most rich biocoenoses are associated with the upper half of the section. Among ostracodes, those of the genera *Paleodarwinula* and *Prasuchonella* are the most common, *Darwinuloides* and *Sinusuella* are less abundant. Ostracode biocoenoses are characterized by rather large den-


56°
57°
SALAVAT
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Belaya
Belaya
53°
53°
Kumertau
Tugostemir
Nakyz
Bolshoij Yushatyr
Bolshoij Yik
Salmysh
52°
52°
Sakmara
Sakmara
Sakmara
ORENBURG
Ural
Yelshanka
Sol-Iletsk
Akbulak
51°
51°
55°
56°
a
b
c
d

sities and extents. Clayey or carbonate silts served as biotopes for them. Bivalves are represented by the species of *Palaemutela* and *Palaeanodonta* genus. Their rare localities are associated with clay interlayers.

The first plastic deformations of the hydrochemical sequence and origination of the salt-dome rises in the marginal deflection began with the Ufimian tectonic activation. An opinion exists, that the principal diapirism processes in the South Cis-Urals are associated with the Early/Middle Triassic boundary (Garyainov *et al.* 1973). Nevertheless, analyses of the Upper Permian marine facies spatial distributions show that as early as the beginning of the Kazanian age, many salt domes, as well as anticline structures of the Salmysh zone, were clearly expressed as positive forms of the ancient landscape.

The Early Kazanian cycle

Since the beginning of the Kazanian boreal sea transgression, a predominantly terrigenous sedimentation regime was established in the Cis-Urals, under the shelf-zone conditions of an extensive basin with its central part in the Volga region and in the north of European Russia (Forsh 1955).

The transgression proceeded in a relatively calm hydrodynamic setting with gradual change of continental and marine series. With gradual basin deepening, formation of a grey-bed sequence began, consisting of pyritized clays and siltites with subordinate sandstone interlayers and solitary thin layers of limestones.

Great abundance of thinly dispersed plant organics and a stagnant hydrodynamic regime within subaquatic depressions favoured the formation of a reducing environment with pronounced hydrogen sulphide contamination.

Bottom water geochemistry caused the impoverished biocoenoses in the lower horizons of the Kazanian stage; those are mainly represented by small-sized thin-walled brachiopods of the genus *Lingula*.

The Kazanian transgression maximum was accompanied by a general normalisation of the hydrochemical regime, first of all, in the elevated areas of the sea-bottom. It was there, in the well-aerated, clean shoal sites, that organogenic-clastic limestones started to accumulate, with diverse and rich communities of brachiopods, bryozoans, algae, corals, crinoids, foraminifers and ostracodes.

Fig. 2. — Location of the Upper Permian sections in south-east of the Russian plate and Cis-Ural Deflection. **a**, natural section; **b**, well; **c**, structural limits of Cis-Ural Deflection; **d**, limit of Peri-Caspian Depression. Others symbols of legend in figure 6. Sections numbers: **1**, Novo-Kandaurovka (the Chekushu - the Sukhalya River tributary), **2**, Korneyevka, the Sukhalya River; **3**, Yumaty, the Sukhalya River; **4**, Yalchikayevo, the Shaltanka River; **5**, well 104, Byelozyorka, the Salmysh River; **6**, Karmalka, the Salmysh river; **7**, well 124, Petrovka; **8**, well 122, Verkhni Gumbet; **9**, well 123, Voskresenskoye; **10**, well 13[su], the Shestimir River; **11**, well 12[su], the Shestimir River; **12**, Nizhni Babalar; **13**, well 388, Yangiz, **14**, the Shestimir River; **15**, well 152[k], Maryevka, the Salmysh River; **16**, well 157[k], Maryevka; **17**, Brody Spring; **18**, well 3, Brody; **19**, well 43[k], Tiryak-Lizyak; **20**, well 48[k], State farm Oktyabrskij; **21**, well 55, Budyonnovskij; **22**, well 52[k], Anatolyevka, the Salmysh River; **23**, well 2[k], Sakmara; **24**, well 1[k], Sakmara; **25**, well 31[k], Grebeni; **26**, Krasny Gully, Grebeni; **27**, 5[k], Grebeni; **28**, well 7[k], Grebeni; **29**, well 39[k], Grebeni; **30**, well 6[k], Chebenki; **31**, well 30, Nezhenka; **32**, Orenburg. **33**, well 70[k], Bolshoj Sutak; **34**, well 94[k], Bolshoj Sutak. **35**, well 80, Dzhuan-Tyubinskaya; **36**, well 79[k], Dzhuan-Tyubinskaya; **37**, well 98[k], Karavanny; **38**, well 59[i], Boyevaya Mt.; **39**, well 60[i], Boyevaya Mt.; **40**, well 53[i], Boyevaya Mt.; **41**, wells 81[k]-87[k], Krasnoyarka; **42**, well 73[k], Kamennaya; **43**, Yelshanka; **44**, Korneyevka, the Yarykly River; **45**, Yeldashevo, the Yurgashka River; **46**, Skvorchikha, the Yergabusha River; **47**, Ostpovka, the Budenya, **48**, Karatajka, the Teiryuk River; **49**, Rodnikovsk, the Teiryuk River; **50**, Verkhotor, the Tor River; **51**, Voskresenskoye, the Tor River; **52**, Vesyoly, the Nugush River; **53**, Krasnogorka, the Nugush River; **54**, Lipovka; **55**, Alexandrovka, the Nugush River; **56**, Yumaguzino, the Meleuz; **57**, Kadyrovo, the Menyu River; **58**, Matakanovo; **59**, Sergeyevskij, the Chukur, Bulyak River, the Bolshoj Yushatur tributary; **60**, Chernigovskij; **61**, Bekechevo, the Nakuz River; **62**, Savelyevskij; **63**, Sankinskij; **64**, Raznomolka, the Tugostemir River; **65**, Slavyanka; **66**, Allaberdino; **67**, Davletkulovo, the Yaman-Yushatyr River; **68**, well 28 and well 43, Davletkulovo; **69**, the Tashla River; **70**, Alexandrovka, the Kuplya River; **71**, Urman-Tashla; **72**, Kasteńskij, the Bolshoi Yushatur River basin; **73**, Maslovskij, the Bolshoi Yushatur River basin; **74**, Smirnovka; **75**, Alebastrovaya; **76**, Cherepanovka, the Burunchar River; **77**, well 41, Staroseika, the Bolshoi Ik River; **78**, Staroseika; **79**, Dmitriyevskij; **80**, well 4 and 5, Dmitriyevskij; **81**, Stary Kazlair, the Chena River; **82**, Novosyolki, the Chena River; **83**, Kholmogory, the Bolshoi Ik River; **84**, Novokulchumovo, the Sakmara River; **85**, well 121, Novokulchumovo; **86**, Vyazovka, the Ural River; **87**, well 102, Vyazovka; **88**, well 19[k], Ostrovnoye, the Ural River; **89**, Blumental Gully, the Burtya river, T.; **90**, Zholtoye, the Sakmara River; **91**, Giryal, the Ural River; **92**, well 73, Activny; **93**, well 44, Verkhneozernoye, the Ural River, **94**, Verkhneozernoye, **95**, wells' profile 5-22, the Burtya River; **96**, **97**, **98**, Tyater River; **99**, **100**, the Net River; **101**, Zildyarovo (Forsh 1955); **102**, Artyukhovka (Forsh 1955), **103-109**, the northern-profile wells of the "Bugurusslanneft" trust (Forsh 1955); **110**, Fyodorovka (Forsh 1955); **111**, Kardaly (Forsh 1955); **112**, Shaktyr (Forsh 1955).

Brachiopods are represented by the genera *Cleiothyridina*, *Stepanoviella*, *Cancrinella*, *Licharewia*, *Dielasma*, *Beecheria*, *Aulosteges*.
Foraminifers, by *Hyperammina*, *Glomospira*, *Ammodiscus*, *Cornuspira*, *Calcitornella*, *Nodosaria*, *Pseudonodosaria*, *Frondicularia*, *Geinitzina*, etc.
Ostracodes, by *Healdia*, *Cavellina*, *Bairdia*, *Actuaria*, *Acratia*, *Amphissites*, *Moorea*, *Pseudoparaparchites*, *Monoceratina*, *Fascianella*, etc.

Calcareous silts and limestones were deposited in local depressions during that period.
The clayey-siltites and limestone members combined constitute the transgressive part of the marine series that maintains its structure within the whole of the South Cis-Urals region. The peculiarities of the spatial distribution of the transgressive thythm facies are presented in the scheme (Fig. 3).
In the north-western part of the region, in the upper reaches of the Salmysh River and in the basins of the Tyater and Ashkadar Rivers, the Lower Kazanian sequence is represented by a complicated inter layering of clays, siltites, sandstones and limestones.
Siltites and clays dominate in the section to the south. The limestone member is present everywhere, but its thickness changes rapidly from 1-2 to 7-12 m.
The transgressive series sediments are up to 90-100 m thick in the north-western part of the region; the thickness decreases to 50-60 m regularly to the south and to the east.
The Kazanian sea regression was accompanied by rapid shallowing of the eastern shelf, where a member of grey-coloured cross-bedded sandstones and sandy siltites was formed, completing the section of the Kazanian marine deposits.
In the western part of the deflection, marine sedimentation proceeded under the same conditions as in the adjacent regions of the platform; this is shown by the uniform facies sequence within stratigraphic sections.
The extreme point where marine formations are established within the deflection is located on the eastern flank of the Dzhuvan-Tyubinskoye rise (E-SE of Orenburg), close to the western salt-dome range (Fig. 3, No. 36). This rise-system was probably controling the position of the Kazanian sea shore-line during its maximum transgression.
A terrigenous sedimentation regime under the conditions of a brackish-water basin was established in the central part of the deflection at the beginning of the Kazanian age. Marine facies analogues are represented by a sequence of dark-grey siltites, clays and fine-grained sandstones, saturated with dispersed plant detritus (Fig. 3, No. 87, 88).
Non-marine ostracodes, *Paleodarwinula* and *Darwinuloides*, occur within them, as well as the Belebej complex bivalves (*Palaeomutela* and *Palaeanodonta*) and a spore-pollen complex, analogous to the Early Kazanian marine-bed palynocomplex in its composition.
The eastern part of the deflection at the beginning of the Kazanian age has become an active homogenic sedimentation zone; the products of this sedimentation are traced within a narrow (10-12 km) piedmont band over more than 100 km, from the Tashla river in the south to the Tor and Nugush rivers close to the northern extremes of the Belskaya Depression (Fig. 3, No. 51, 61). Dolomites, dolomitised limestones and marls, and, to a lesser extent, grey-coloured clays and siltites were accumulating there. Siltitic-clayey sediment became dominant in the section while the basin was gradually freshening and the terrigenous drift became more intensive.
Ostracode and mollusc biocoenoses are concentrated within the upper, less mineralised horizons of the lagoonal sequence. They are represented by brackish-water species of *Darwinuloides* and *Paleodarwinula*, common for the whole of the Kazanian stage; that is why correlation of these facies to marine deposits from the western regions is established from palynologic data (Kuleva 1975). The whole of the 150 m thick lagoonal sequence, irrespective of its rock-compositions, is distinguished for extremely low magnetisation ($Jn = 0.5\text{-}1.5 \times 10^{-5}$ A/m, $\varkappa = 214 \times 10^{-5}$ SI units). The lack of magnetic material in the sediments shows that the lagoon was completely isolated by the surrounding salt-dome rises. The terrigenous drift was later on accomplished at the expense of baring of the Lower Permian and Carboniferous weakly magnetised terrigenous and carbonate sequences

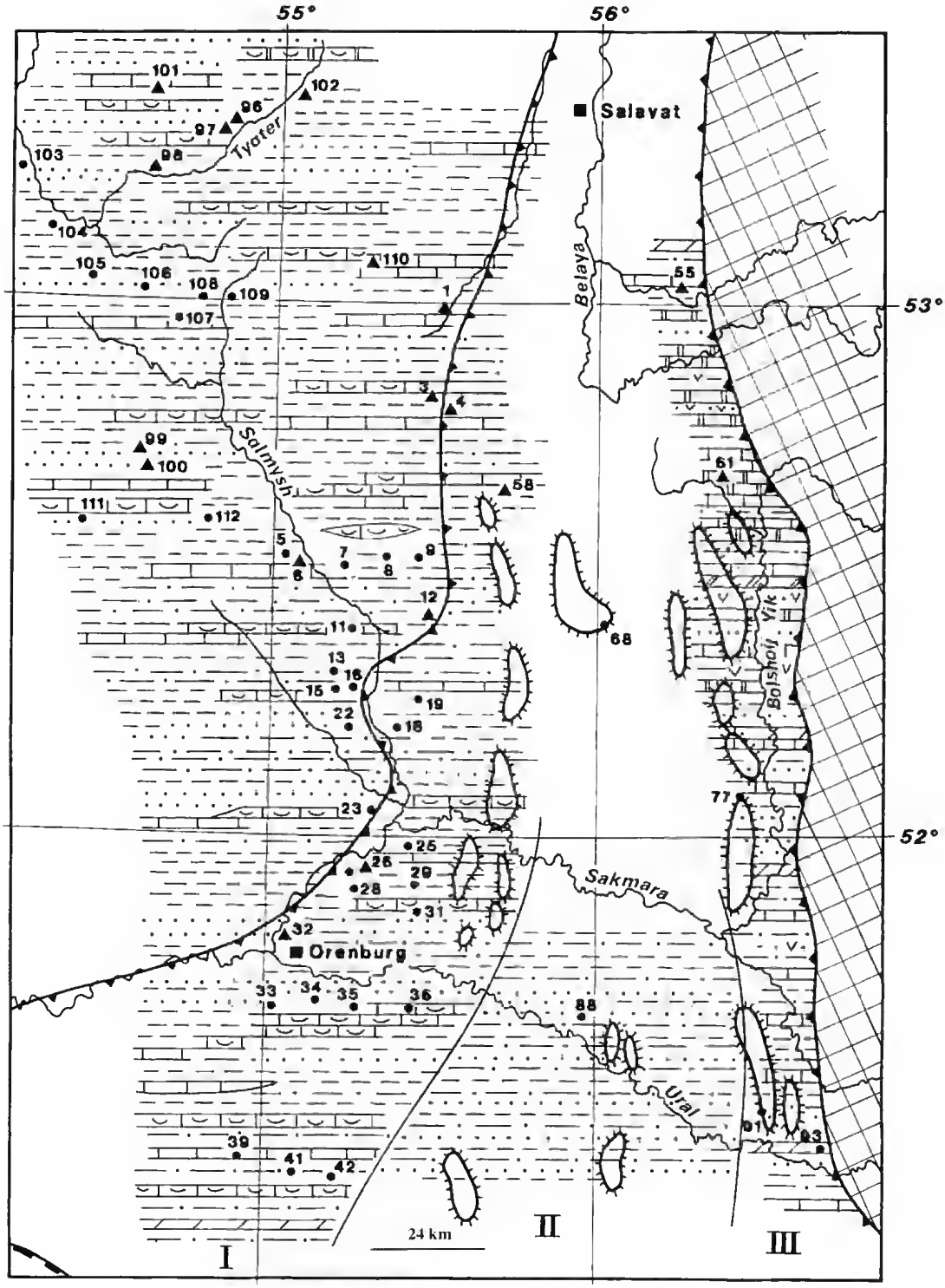

FIG. 3. — Lithofacies scheme of southern Cis-Ural - early Kazanian (legend in figure 6).

from the western slopes of the Urals.
No lagoonal facies have been reliably revealed in the southern part of the eastern zone, and the Lower Kazanian substage was thought to comprise the grey-coloured sequence of alluvial-deltaic sandstones and siltites with rare clay and marl interlayers, containing the remains of freshwater bivalves and land vertebrates (Kuleva & Tverdokhlebov 1974).

The late Kazanian sedimentation cycle

The middle of the Kazanian age represented a turning point in the South Cis-Urals geologic history. A continental sedimentation regime has finally established itself in the region as the result of the Urals tectonic activation and the Boreal Sea regression towards the centre of the Russian Plate.
The Cis-Ural Deflection and the adjacent regions of the Platform have changed into an extensive accumulative plain with a complicated combination of basin, lagoonal, lacustrine and alluvial-proluvial facies; both southern and latitudinal zonings were evident in their spatial distributions (Fig. 4). In the south, within the Ural and Salmysh Rivers Basins, basinal terrigenous sedimentation has established itself, and a monotonous interlaid sequence was accumulating of siltites, clays and fine-grained sands with single interlayers of marls and obliquely-laminated polymictic sandstones of deltaic type. In the western part of the deflection and in the platform, mostly red-bed sediments were developing. In the south of the central zone of the deflection, a sequence was formed of interlayering red-beds and grey rocks.
The principal portion of the deflection central zone was occupied by a lacustrine-alluvial plain, accumulating a complex of red-coloured aleuro-pelitic deposits with subordinate interlayers of fine-grained sands and clayey limestones. A limited amount of sandy-conglomerate facies of channel alluvium is represented in the section.
The northern regions, embracing the Nugush, Belaya and Dyoma basins, were occupied by a major interior reservoir with increased mineralisation; it was limited with a number of salt domes from the south. An interlayering sequence of siltites, clays, limestones and marls has accumulated within it. Sulphates were precipitating at some sites (Kochetkova 1970).
A narrow piedmont band along the eastern border of the deflection comprised an alluvial-proluvial plain, where the principal part of the sandy-pebble material carried from the mountain Urals was deposited (Kuleva & Tverdokhlebov 1974).
The beginning of the Late Kazanian sedimentation cycle is clearly recorded in the section from the central and eastern zones of the deflection by sharp increases of rock scalar magnetic characteristics. At this boundary, the Jn and æ values increase up to 0.1-0.2 A/m and 300-500 × 10^{-5} SI units, respectively. The very character of the section petromagnetic in homogeneity testifies to a volley ejection of great amounts of terrigenous material from the Urals eastern slopes (Fig. 7).
Diverse sedimentation settings in the Cis-Urals have affected the structure of the Late Kazanian aquatic biota, which is distinguished for its species diversity, being relatively limited in the number of genera. Ostracodes of *Prasuchonella* genus dominated in the aleuro-pelitic grounds in the zones of mobile hydro-dynamics and sulphate mineralisation of waters. Calcareous and calcareo-dolomitic grounds served as an ecological niche for srenofacial *Darwinuloides*. The clayey-calcareous lithofacies were occupied by *Paleodarwinula* and *Prasuchonella*. *Paleodarwinula* proved to be the only ones to adapt themselves to the non-carbonate silty grounds.
Widely occurring bivalves are represented by the brackish-water species of *Palaeomutela* and *Palaeonodonta*, which possessed thin-walled shells and preferred the silty sediments of hydrodynamically calm zones (Kuleva 1975, 1979).
Beside ostracodes and bivalves, few conchostracans and fish were present in the aquatic biotopes. Swamp coastal plains served as habitats for terrestrial plants and tetrapods.

The early Tatarian sedimentation cycle

The early Tatarian paleogeographic setting was determined by tectonic activity in the whole of the South Cis-Urals.
In the western part of the region, the deposits, assigned to the lowermost of the Tatarian, were

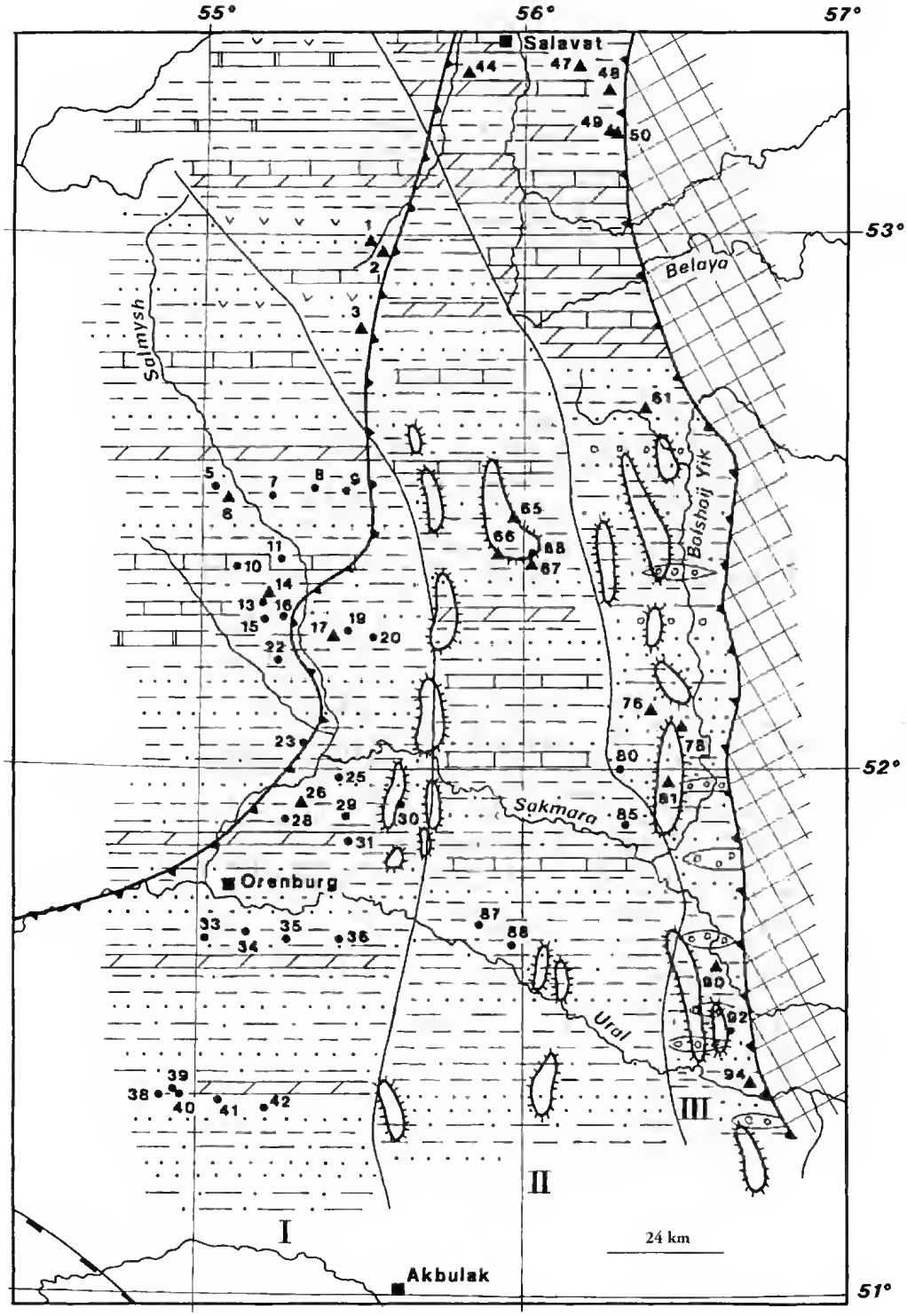

FIG. 4. — Lithofacies scheme of southern Cis-Ural - late Kazanian (legend in figure 6).

being formed in the inherited late Kazanian reservoirs with increased mineralisation. Gypsinates and stones were depositing there (Fig. 4).
High sulphatisation of the reservoirs was adversely affecting the organic life development. The clayey-aleuritic grounds there were inhabited only by ostracodes of *Prasuchonella* genus, sometimes associated with rare depressed *Paleodarwinula*. Carbonate silts are associated with the localities of *Darwinuloides ischerdinzevi* Kashevarova, a typical dweller of highly mineralised carbonate reservoirs with increased magnesiality (Molostovskaya 1974).
The principal cycle of the early Tatarian sedimentation began with vast alluvial plain development; the plain is traced by a characteristic facies set in the form of a southern band to the south from the Bashkir Cis-Urals, right to the town of Sol-Iletsk. The alluvial sequence is composed mostly of cross-laminated channel sandstones and pebbles of local rocks. Less common are red-coloured aleuro-pelites of the flood plain and dead-channel facies.
In the second half of the early Tatarian cycle, the alluvial sedimentation was changed in the basinal one; its products appear in the upper horizons of the section over the sequence of alluvial sands, in the form of a member of siltite-clayey beds (Fig. 5, No. 31, 36, 42).
Eastwards, the lower Tatarian alluvial plain turned into the lacustrine-alluvial one, occupying the greater part of the central and eastern zones of the marginal deflection. A monotonous sequence of red aleuro-pelitic silts was deposited within it, with interlayers of alluvial sands and conglomerates.
Along the northern fringes of the lacustrine plain, in the basins of the Nugush, Tor and Belaya Rivers, an alluvial-deltaic regime was established during the initial stages of the Early Tatarian sedimentation; this resulted in a thick (300-400 m) sequence of cross laminated sands, gravelstones and conglomerates. Later on, a reservoir with increased water-mineralisation was formed in this territory; pelitic and carbonate silts were precipitating there (Kochetkova 1970).
In the eastern flank of the marginal deflection, the regime of alluvial-deltaic and proluvial sedimentation dominated (Fig. 5, No. 45, 46, 50, 51, 52). Within a narrow piedmont band there, a major portion of coarse clastic material was deposited; judging from its composition, this was carried from the central and western parts of the mountain Urals. According to Kuleva & Tverdodokhlebo (1974), quartz, flints, quartzites, Carboniferous and lower Permian limestones dominated in the lower Tatarian pebble stones. A significant part of the piedmont molasse consists of the proluvial material with its typical "rubbish" horizons, comprising unsorted sands, pebble stones and aleuto-pelitic sediments.
Among the organisms, inhabiting the early Tatarian reservoirs, bivalves and ostracodes are the most abundant ones. Aleuto-pelitic sediments of the flood plain type are associated with the localities of bivalves of the Kama and Chepetsk complexes, consisting of the *Palaeomutela*, *Anthraconaia* and *Palaeanodonta* genera representatives. Ostracode *Paleodarwinula* and *Paleodarwinula-Prasuchonella* communities are also associated to the same facies.
The sedimentation setting of an alluvial plain is chiefly characterised by numerous accumulations of thick-walled shells of the Doskinsky complex. The typical species of this complex, *Antraconaia verneuili* Amalizky, is a typical inhabitant of the channel facies (Kuleva 1975).
Paleodarwinula are the most common of ostracodes there.
Highly mineralised carbonate reservoirs provided rather favourable conditions for biota development. In the clayey-carbonate rocks there, alga fragments, fish scales, bivalve and ostracode shells occur. Ostracodes are most abundant. They are represented by diverse communities: *Darwinuloides*, *Darwinuloides-Paleodarwinula*, *Paleodarwinula*, *Paleodarwinula-Prasuchonella* and *Prasuchonella*.
The specific features of the changing paleogeographic setting are clearly recorded by scalar petromagnetic characteristics. In the reference sections from the central and eastern zones of the Cis-Urals Deflection, the beginning of the Early Tatarian sedimentation is marked by a sharp 4-5 fold decrease in rock magnetisation of red-bed molasse: to modal $\varkappa$ values 25-30 $\times 10^{-5}$ SI units with rare "bursts" up to 70-90 $\times 10^{-5}$ SI units (Molostovsky 1969).

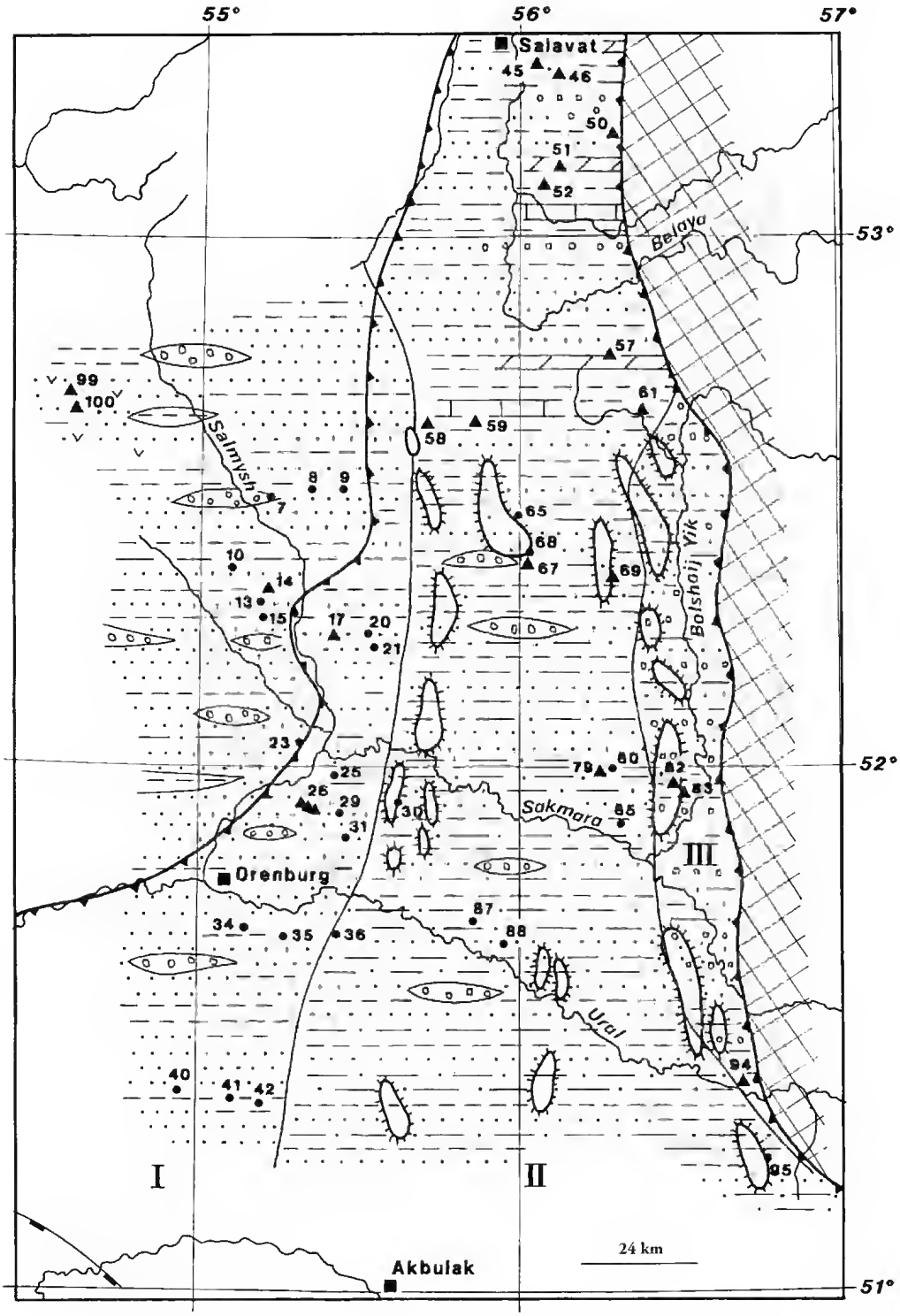

FIG. 5. — Lithofacies scheme of southern Cis-Ural - early Tatarian (legend in figure 6).

In the western part of the deflection and in the adjacent regions of the Russian Plate, the changes in the facial settings almost didn't affect magnetisation of the sediments. The basin deposits of the Kazanian age and the cross-laminated sandstones of the lower Tatarian alluvial plain are distinguished for extremely uniform decreased magnetisation with the modal Jn values of 6-9 × 10^{-3} A/m and those of æ = 12-20 × 10^{7} SI units (Fig. 7).

The peculiarities of petromagnetic section structures show that in the period of the early Tatarian sedimentation, the whole of the South Cis-Ural territory was to a significant extent isolated from the Trans-Ural source provinces. The central and eastern zones of the deflection were being filled with the terrigenous material from the sedimentary and metamorphic sequences of the western slopes of the Urals. The source lands to the western alluvial plain were probably situated in the north, in the regions of the Tatar and Bashkir Archbends, where the weakly magnetised horizons of the sedimentary cover were exposed to wash-out. Local source centres might originate within the arch porrions of the local rises.

The late Tatarian sedimentation cycle

The late Tatarian sedimentation was preceded by the Urals ascending motions. This rising has probably involved the Salmysh Bar zone, characterized by the absence of the upper Tatarian deposits. Stable accumulation was preserved only within the deflection enclosing the marginal zone of a large epicontinental basin territorially connected with the Peri-Caspian Depression. The non uniform hydrochemical settings in the reservoir have predetermined the southern zoning in its facies spatial distribution.

Its western part, the most spread one, has become a site for terrigenous sedimentation which resulted in a homogenous sequence of interlayering red clays, siltites and fine-grained sandstones. The band of terrigenous accumulations was traced along more than 150 km from the north to the south (from Bashkiria to the town of Sol-Iletsk), but its real extent hasn't been established. This facial zone is limited by a southern band of the Kungurian rises and the Cis-Ural Deflection border to the east and to the west (Fig. 6: I).

The red-bed sequence acquires a somewhat more variegated, poly-component composition to the east, within the central zone of the deflection. Siltites and clays constitute the sections principle components there. The amount of arenaceous sediments insignificantly reduced, thin gravelite and pebble stone lenses appear, limestone and marl interlayers and calcareous clay members are encountered with accumulations of carbonate nodules and concretions.

Sediments carbonate contents increase regularly from the north to the south, and marls and limestones become important components of the sections from the basins of the Tor, Nugush and Belaya Rivers (Fig. 6: II).

The conditions of the upper Tatarian sequence formation within the central part of the deflection are analysed in detail by Botvinkina and Tverdokhlebov. Botvinkina (1962) reconstructs the hydrodynamic settings of the large marine-type basin. In Kuleva & Tverdokhlebov schemes (1974), this territory is assigned to a lacustrine-swamp plain with the accumulation level close to zero.

Significant deposit thicknesses (> 500 m), fossil-remains compositions, numerous intra-formational gaps testify to dynamic hydrogeologic regime of sedimentation against the background of intensive basin-floor deflection. This data more likely conforms to the hypothesis of a large reservoir penetrating into the low land as narrow intrusive tongues, and reaching distant northern areas, right to the periclinal closure of the Belaya depression.

In the eastern piedmont flank of the marginal deflection, similar to the early Tatarian time, a narrow alluvial-proluvial plain was situated, cut by permanent and temporary water flows. Numerous fans are formed within it, consisting of sandy, boulder-pebble and gravel materials. Limestones, flints, quartzites and variously composed effusives occur among clasts (Fig. 6: III).

The upper Tatarian deposits are distinguished for diverse petromagnetic characteristics with some certain ordering in their spatial distributions.

The pelitic arenaceous sediments from the western facial zone are marked with weak uniform magnetisation and are practically identical to the lower and upper Tatarian formations in Jn and æ values.

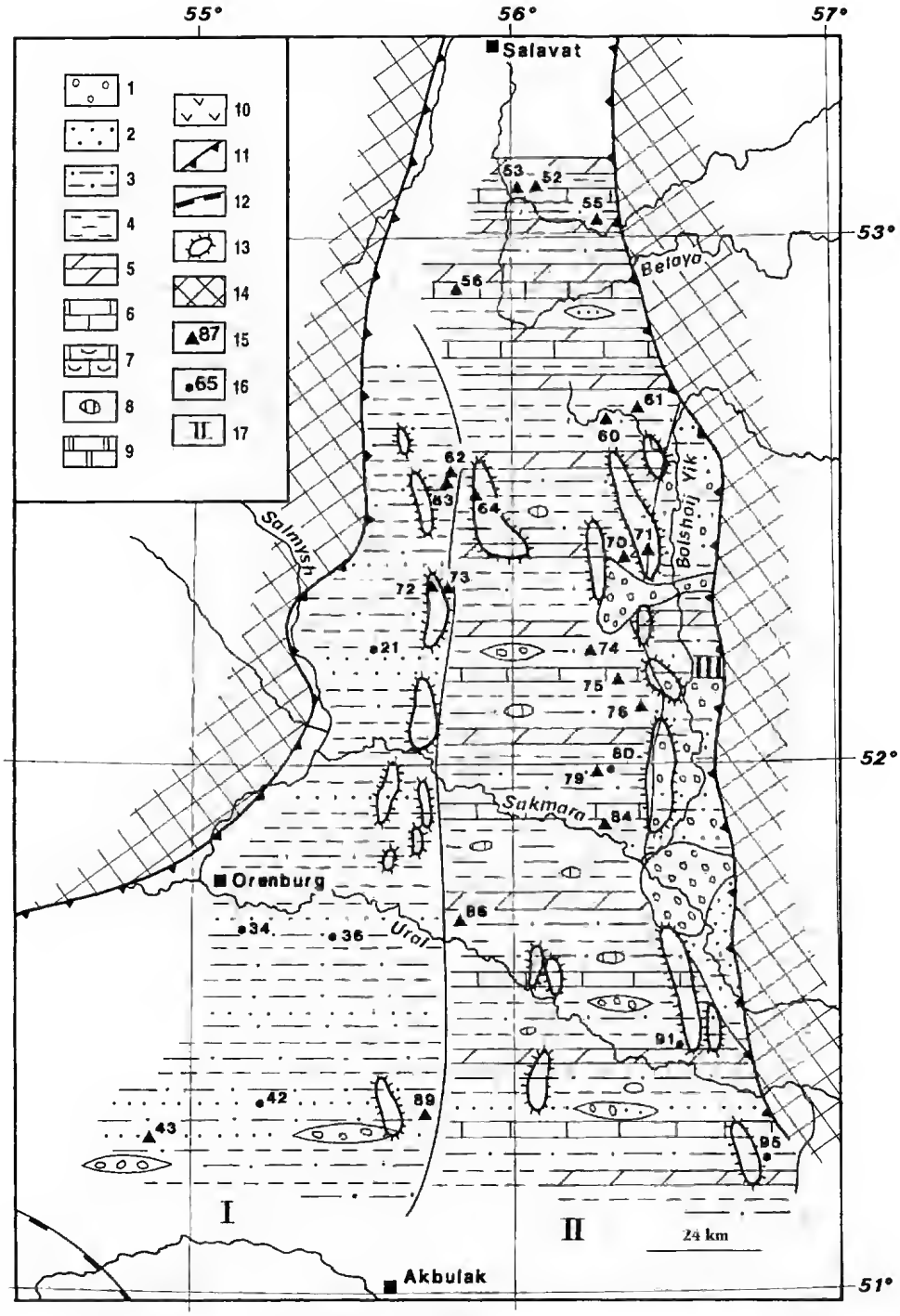

Fig. 6. — Lithofacies scheme of southern Cis-Ural - late Tatarian. Symbols for figures 2-6: **1**, conglomerates; **2**, sandstones; **3**, siltites; **4**, clays; **5**, marls; **6**, limestones; **7**, organoclastic limestones; **8**, nodular limestones; **9**, dolomites; **10**, gypsums; **11**, boundary of Cis-Ural marginal Deflection; **12**, boundary of the Peri-Caspian Depression; **13**, growing salt domes; **14**, land; **15**, outcrop; **16**, well; **17**, structural facies zones.

In the eastern and central zones of the deflection, the sequences are distinguished for extremely high non uniform magnetisations with Jn and æ values of tens and hundreds of SI units. A sharp change of weakly- and strongly-magnetisation sequences is recorded within the wells of the profile 95 (the Burlya River basin); the level of this change is practically coincident with the lower/upper Tatarian boundary (Fig. 7).

The petromagnetic data comparison makes it evident that the late Tatarian sedimentation was accompanied by the change of the source lands and that the central part of the deflection was still a kind of an accumulative bath, receiving practically all the magnetic materials carried in from the greenstone belt of the eastern Urals.

The ecological setting was favourable for the development of a rich and diverse aquatic biota. On the clayey-aleuritic grounds within the zones of relatively calm hydrodynamic settings, thin-shelled bivalves of the Vyazovsky and Oksky complexes resided, represented by *Palaeomutela*, *Palaeanodonta* and *Anthraconaia* genera. The coastal zones with moderately active hydrodynamics were occupied by the Severodvinsky complex bivalves, including *Palaeomutela*, *Palaeanodonta*, *Oligodontella* and *Opokiella* genera (Kuleva 1975).

Multiple and variously composed ostracode communities were distributed over clayey-aleuritic and carbonate grounds. The eury-facies *Suchonellina* dominated in the late Tatarian biotopes, forming independent communities there or associated with *Suchonella*, *Dvinella*, *Wjatkinella* and *Gerdalia* (Molostovskaya 1993). The steno-facies *Sinusuella*, *Permiana* and *Placidea* were usually localised within the bottom-water zones of increased carbonate mineralisation. Their rare localities are associated with marl-carbonate layers.

In the eastern zone of the deflection, an ostracode association was formed, consisting of the representatives of *Suchonellina*, *Suchonella* and numerous small endemic Cytheracopina, possessing little, elongated, sculptured shells. In their morphologic features, the latter ones are close to

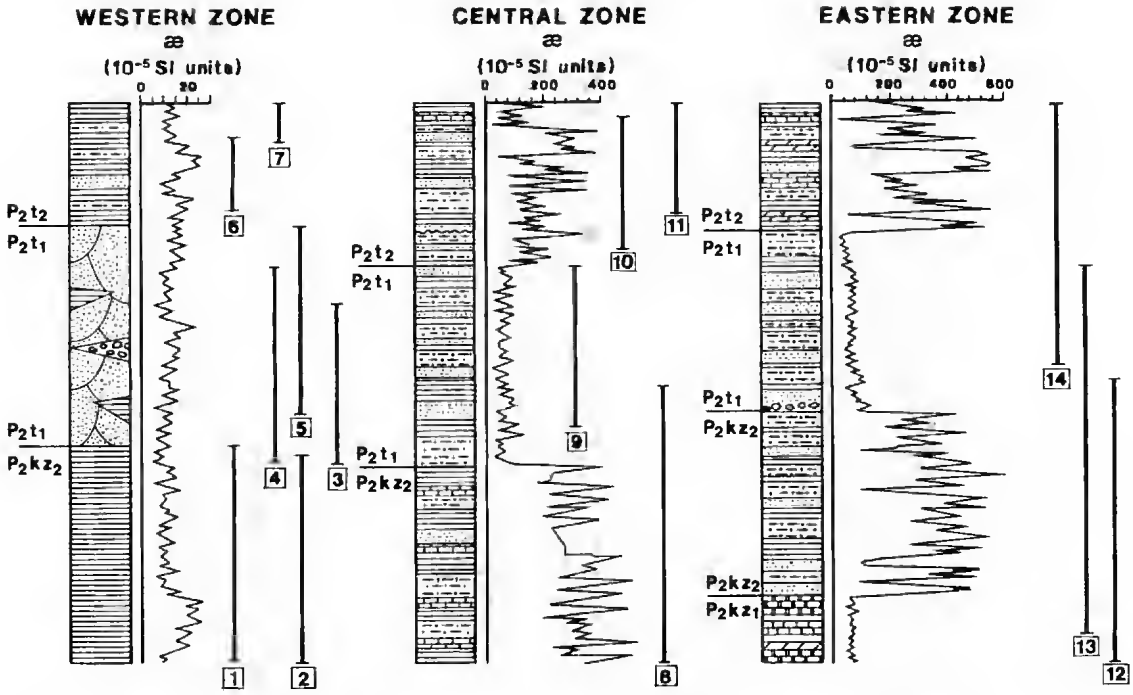

FIG. 7. — Petromagnetic curves of the Upper Permian deposits in Cis-Ural Deflection. **1**, Krasny Ravine; **2**, well 31ᵏ, Grebeni; **3**, Shestimir River; **4**, Sakmara; **5**, Brody; **6**, Yelshanka; **7**, Blumental; **8**, Davletkulova, Yaman-Yushatyr River; **9**, Sergeevsky; **10**, Vyazoka; **11**, Novokulchumova; **12**, Bekecheva, Nakyz River; **13**, Nugush River; **14**, well profile 22, Burly River.

the Triassic Cytherocopina from the Peri-Caspian Depression, but differ substantially from the upper Permian Cytherocopina from the Russian Plate. This specific complex is territorially limited within a narrow piedmont band of the marginal deflection, traced from the south to the north for over 200 km (from the Burlya River to the basins of the Tor and Nugush Rivers).

Conchostracans, gastropods, *Spirorbis* worms and algae were common, but not numerous inhabitants of the Tatarian reservoirs; their fossilised remains are also concentrated in clayey-carbonate rocks.

The marsh-ridden coastal areas of the low land served as an ecological niche for small tetrapods.

Considering various aspects of the Late Permian paleogeography of the South Cis-Urals, it is a matter of principle to realise the extent this rather peculiar local region was related with the Tethys northern fringes during its evolution. Spatially and structurally, the southern part of the Cis-Ural Marginal Deflection is continuous with the eastern part of the Peri-Caspian Depression. It is natural that correlations of stratigraphic sections and lithofacies features of the Upper Permian deposits from these regions present a special interest.

The detailed information on the structure of the Upper Permian formation from the Peri-Caspian Depression is given in the papers of Movshovich (1977), Vainblat (1969) and Zamarenov *et al.* (1969). A comparative analysis of the data on the South Cis-Urals and the Eastern Cis-Caspian reveals significant section similarities lithology, chronological succession of facies, stratigraphic boundaries character and bionomic characteristics. These similarities are especially evident for the Kazanian and Tatarian stages.

Within the Cis-Ural Deflection, as well as in the eastern Cis-Caspian region, the Kazanian stage is represented by non-marine brackish-water facies with terrigenous compositions. In the lower portion of the section, grey-coloured argillites and siltites dominate, saturated with thinly dispersed plant detritus and authigenic iron sulphides.

The upper Kazanian substage is everywhere represented by the sequences of interlaid grey- and red-coloured rocks with the latter ones clearly dominating. Vainblat (1969) and Zamarenov *et al.* (1969) suppose that the Kazanian sedimentation took place within extensive shallow-water reservoirs, experiencing hydrostatic head from the boreal basin at various stages. Lagoonal and deltaic sedimentation proceeded in individual sites.

The Tatarian stage from the eastern Cis-Caspian, as well as from the Cis-Urals, is represented by a red-coloured complicated structured terrigenous sequence, comprising variously rationed alternations of argillite and aleuro-psammite beds with rare limestone interlayers.

The total numbers of the Upper Permian sedimentation cycles in both regions are identical; it is significant, that all the stage and substage boundaries are marked with stratigraphic, and in the Cis-Caspian by angular discordances.

The peculiarity of the Upper Permian deposits from the eastern part of the Peri-Caspian Depression consists in their saturation with pebble-stone material, including flints, quartz, metamorphic shales and effusives, *i.e.* practically the whole of the typomorphic set of rocks from the central and eastern Urals.

The Ural material is present practically all over the eastern fringe of the Peri-Caspian Depression (from the Cis-Ural Deflection to the Emba River).

The lithofacies information obtained from drilling, plays a certain role in the long discussion tectonists hold on the structure of the Cis-Ural Marginal Deflection within the Peri-Caspian Depression. Goretsky (1972), Shlezinger (1974) and some other authors advocate the idea of the Cis-Ural Deflection passing into the system of periclinal deflections fringing the folded Urals from the south and south-west. Movshovich (1977), Mizinov (1974), Lapkin & Tomashunas (1966) and others provide diverse arguments in favour of the idea of an abrupt turn of the Ural folded system and the Cis-Ural Deflection to the west and their jointing the Karpinsky Ridge and the Cis-Donets marginal deflection in the northern Cis-Caspian, between Gurjev and Astrakhan.

Great abundance of pebble material in the south of the Peri-Caspian Depression represent rather substantial arguments in favour of the second conception.

The ring of the Hercynian structures during the whole of the Late Permian was acting as an effec-

tive batrier isolating the epicontinental Cis-Caspian basin from the Tethys. The Cis-Caspian geographic isolation from the region of marine sedimentation has affected the structure of the Upper Permian biota, which in its ostracode and bivalve composition was very similar to those from the Russian Plate and the Cis-Ural Marginal Deflection. In the sections from the Cis-Caspian region, ostracodes are represented by *Darwinula*, *Darwinuloides*, *Suchonella*, *Suchonellina* genera. Among bivalves, the brackish-water genera *Palaeomutela* and *Palaeonodonta* are indicated.

Lithologic-facies and paleontologic records testify to the autonomous development of the epicontinental Cis-Caspian reservoir in the Late Permian and don't provide any more or less substantial arguments in favour of its recurrent connections with the Tethys.

CONCLUSION

The mean features of the Late Permian paleogeography in the South Cis-Urals were determined by the tectonic activity of the Ural orogen, and in the beginning of the Kazanian (by an extensive boreal transgression). Each sedimentation cycle was preceded by the Urals uplifting, baring processes animation within the source lands and regional wash-outs in accumulation basins. Consequently, the boundaries between the Upper Permian stratigraphic units are of episodic character and correspond to the initial stages of sedimentation cycles.

The central and the eastern zones of the marginal deflection, during the whole of the Late Permian epoch, existed as a major depression morphostructure, accumulating the main portion of the allothigenic material arriving from the region of the folded Urals. The western part of the deflection, in its present configuration, has a lot in common with the adjacent areas of the Russian Plate in lithology and thicknesses, and constitutes a single structural-facies zone with the Plate.

One may suppose that the western border of the deflection in the end of the Permian was situated to the east of its present position and ran over the zone of the southern Kungurian elevations. Thus, some migration of the deflection axis towards the Platform is outlined, which is generally characteristic of such structures type.

Southern zoning is outlined in the lithofacies spatial distribution within the marginal deflection; a sufficient role in this deflection origination was played by the western and eastern zones of linear elevations of the Kungurian halogenic sequence. Besides, the sub-latitudinal zonality is outlined in distribution of the evaporite and terrigenous facies; this zonality persists at all the stages of the Late Permian sedimentogenesis: from the Ufimian through the late Tatarian.

The main portion of the sulphate-carbonate accumulations is concentrated in the northern part of the region, where a system of inherited lagoon-type reservoir is known to have existed for a long time. The terrigenous sedimentation in the southern regions is most logically explained by an active river discharge and, consequently, by accumulation - basins freshening. The analyses of thicknesses, facies and organic remains compositions, demonstrate that generally basin sedimenration regime prevailed in the south of Cis-Urals, with wide development of low accumulative plains characterised by alluvial-proluvial and lacustrine-swamp sedimentation.

Not withstanding peculiar paleogeographic settings, caused by the proximity of the mountain Urals, the South Cis-Urals region in its geologic development was closely related both to the marginal part of the Russian Platform and to the Peri-Caspian Depression.

The Cis-Ural Deflection reveals a lot of similarities with the eastern part of the Peri-Caspian Depression in lithology, facies set and biota composition. It used to represent just a narrow gulf of an extensive epicontinental reservoir.

An active material discharge from the Mountain Urals region constitutes a peculiar feature of the Late Permian sedimentogenesis in the eastern Cis-Caspian and South Cis-Urals. The influence of the Urals is revealed all over the eastern fringes of the Peri-Caspian Depression: from the Ural River valley in the north to the Emba Rivet basin in the south.

The analyses of the data on the upper Permian deposits from this region show that the intracontinental basin of the Cis-Caspian in the Late

Permian was developing in an autonomous regime and didn't have any long-term connections with the Tethys area. The natural barrier between them consisted of the system of the Hercynian mountain structures of the Urals and Karpinsky Embankment, joining each other in the zone of the present-day Caspian aquatorium, in the area between the Ural and the Volga mouths. This isolation was broken up in the Olenekian age and in the Middle Triassic, when major invasions of the Tethys into the Cis-Caspian region occurred. No events of similar scale have been revealed in the Late Permian, but this problem needs special studying.

In this connection, the communities of intricately-sculptured Cytheracea seem rather interesting; they appeared in the south of the Cis-Ural Marginal Deflection in the second half of the Tatarian age. In their morphologic features they are similar to certain Cytheracea from the Middle Triassic Cis-Caspian complex, which, according to Lipatova & Starozhilova (1968), is analogous to the ostracode complex from the Middle Triassic of Germany. Very small ostracodes with smooth-valve shells also occur there; they are morphologically similar to *Paracypris*, the representatives of which are common mainly in seas. Origination centres and movement tracks of these ostracodes are still unknown. They may prove to be endemic, but one can't rule out the possibility of their being some southern migrants, to certain extent associated with the marginal part of the Tethys.

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Ichthyofaunal correlation of the Triassic deposits from the northern Cis-Caspian and southern Cis-Urals regions

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ABSTRACT

All the known data on the Triassic ichthyofauna from south-east European Russia are summarized. The material studied comes from thirty-nine localities from the Lower and Middle Triassic reference and stratotype sections of the South Cis-Urals and northern Cis-Caspian regions. Data on terrestrial vertebrates, ostracodes, and charae are used as well as paleomagnetic sampling results. A certain stratigraphic importance of the Triassic gnathorhiza and ceratods is demonstrated relative to lungfish, the one of hybodontids relative to squaliforms and the one of saurichthiids among actinopterygians. Two super-ichthyocomplexes were revealed within the Triassic sections according to dipnoan distributions: those of gnathorhiza and ceratods. Their change in the region occurs in the middle of the Olenekian age and is associated with the rather short Akhtuba time in the Cis-Caspian and with the synchronous Fyodorovka time in the South Cis-Urals. Considering the data on other fish groups, three independent ichthyocomplexes are recognized in the Triassic ichthyofauna: the Vetlugian and Yarenian ones in the Early Triassic and another one in the Middle Triassic. The Yarenian ichthyocomplex comprises two clearly manifested groups of different ages (the Akhtuba and Bogdo ones in the Cis-Caspian and the Fyodorovka and Gamskaya ones in the South Cis-Urals). The Middle Triassic ichthyocomplex comprises the Donguz and Bukobaj fish groups. The regularities revealed in fish-taxa changes with time, are traced within the sections across the adjacent territories from the Cis-Urals to the Cis-Caspian. The Lower Triassic Akhtuba suite from the Cis-Caspian Bogdo section was correlated by fish with the lowermost part of the Petropavlovka suite, and the overlying Bogdo suite with the rest of the Petropavlovka section from the Orenburg region. The Middle Triassic Donguz and Bukobaj suites from the Cis-Urals are stratigraphically analogous to the Elton and Inder suites from the Middle Triassic

KEY WORDS
Ichthyofauna,
Triassic,
northern Cis-Caspian,
southern Cis-Urals.

section in the northern Cis-Caspian. The succession revealed in the Triassic ichthyofauna development is maintained all over the territory of European Russia. It is traced in the adjacent regions and may serve as the basis fot stratigraphic divisions and interregional correlations of different-facies marine and non-marine sections of the Triassic.

RÉSUMÉ

Toutes les données connues sur l'ichthyofaune triasique du SE de la Russie européenne sont compilées. Le matériel étudié provient de trente-neuf localités des coupes de références et stratotypiques du Trias inférieur et moyen du sud du Cis-Oural et du nord de la Cis-Caspienne. Les données sur les vertébrés terrestres, les ostracodes, les characées sont utilisées aussi bien que les résultats paléomagnétiques. Deux super-ichthyocomplexes sont mis en évidence dans les coupes du Trias. Leur changement dans la région se produit au milieu de l'Olenekien, il est rattaché à l'intervalle court de Akhtuba dans la région de la Cis-Caspienne et à l'intervalle synchrone de Fyodorovska dans la région du Sud du Cis-Oural. Considétant les données des autres groupes de poissons, trois ichthyocomplexes indépendants sont reconnus dans le Trias. Le Vetlugian et le Yarenien dans le Trias inférieur et un autre dans le Trias moyen. L'ichthyocomplexe Yarenien comprend deux groupes d'âge différents (l'Akhtuba et le Bogdo dans la Cis-Caspienne et le Fyodorovka et le Gamskaya dans le sud du Cis-Oural). L'ichthyocomplexe du Trias moyen comptend les gtoupes de poissons de Donguz et de Bukobaj. Les changements dans le temps de la faune de poissons sont reportés sur les coupes à travers les territoires depuis le Cis-Oural jusqu'à la Cis-Caspienne. La suite d'Akhtuba, du Trias inférieur, de la coupe de Bogdo (Cis-Caspienne) est corrélée par les poissons avec la partie basale de la suite de Petrovpavlovka, et la suite de Bogdo sus-jacente avec le reste de la suite de Petrovpavlovka dans la région d'Orenbourg. Les suites du Trias moyen de Donguz et Bukohaj (Cis-Oural) sont stratigraphiquement analogues aux suites de Elton et Inder de la coupe du Trias moyen du nord de la Cis-Caspienne. La succession dans le développement des ichthyofaunes du Trias est une constante sur tout le territoire de la Russie européenne, elle est tracée pour les territoires adjacents et peut servir de base pour des divisions stratigraphiques et des corrélations interrégionales des différents faciès marins et continentaux du Trias.

MOTS CLÉS
Ichthyofaune,
Trias,
nord Cis Caspienne,
sud Cis Oural.

INTRODUCTION

In the territory of European Russia, the Triassic deposits are developed in two disconnected extensive fields: the southern and northern ones. The present paper considers the ichthyofauna only from the southern Triassic field, embracing the territories of the northern Cis-Caspian (the Peri-Caspian Depression), the south of the Cis-Ural Marginal Deflection, the southern slope of the Volga-Ural Anticlise (Obshchy Syrt) and, partially, the zone of the Don-Medveditsa dislocations. The Triassic accumulation, as well as the aquatic paleobiota development in these regions, were directly or indirectly controlled by the Tethys paleo-ocean regime. The first paleontologically characterized Triassic deposits in Russia were established within the southern Triassic field, in the Bolshoye Bogdo Mountain, near the lake of Baskunchak in the northern Cis-Caspian. In the middle of the eighteenth century, Pallas (1788) discovered ammonites in the Bogdo limestones; later on, those were described by Bukh (1885) as *Ammonites bogdoanus* Buch.

While making a layer-by-layer description of the same section, Auerbakh (1871) found some remains of labyrinthodont, *Mastodonsaurus* (?) sp., and fish, *Hybodus plicatilis* Agassiz, *Acrodus dunkeri* Auerbach, *Sphaerodus minimus* Agassiz, *Saurichthys* sp. Those fauna-bearing layers are comparable with the Middle Triassic Muschelkalk from Germany. It was only when Mojsisovich (1882) found ceratites in the ammonite fauna of Bolshoye Bogdo, late in the nineteenth century, that the section could be compared to the Campilian layers of the Alpine Lower Triassic. Later on, Khabakov (1932) described two lungfish tooth plates from the Bogdo limestones: *Ceratodus* ex gr. *kaupi* Agassiz, and *C. facetidens* Chabakov. It is worth mentioning

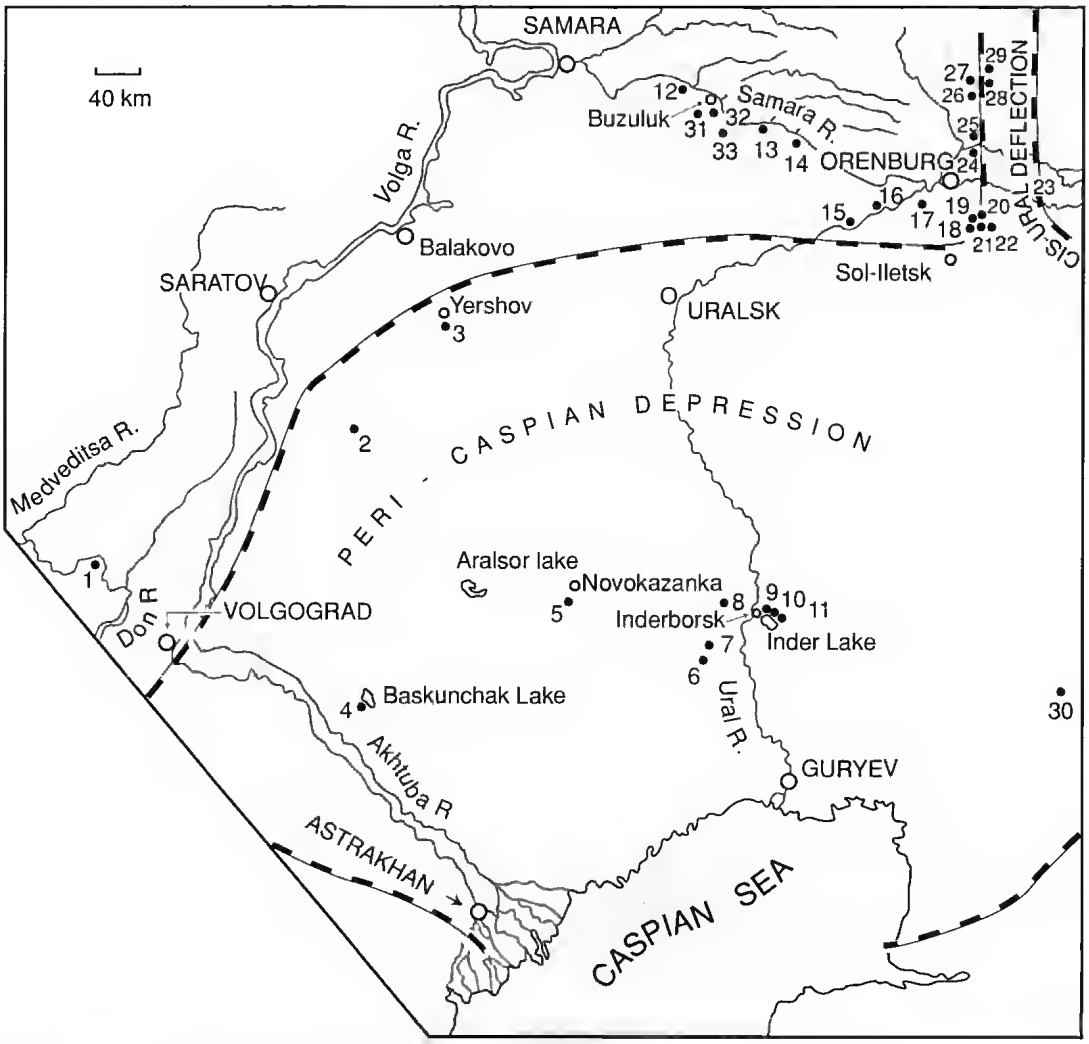

FIG. 1. — Principal Ichthyofauna localities in the northern Cis-Caspian and southern Cis-Ural regions, main sections: **1**, The Don Bend; **2**, Gmelinka, well 5041-c (1521-1526 m int.); **3**, Yuzhno-Yershovskaya, well 1 (931-934 m int.); **4**, Bolshoj Bogdo Mountain; **5**, Novokazanka, well k-6 (424.5-427 m int.); **6**, Zhundykuduk, well 46 (depth 440 m); **7**, Zhundykuduk, well 22 (487-491 m int.); **8**, Barkhanny, well k-4 (358-365.5 m int.); **9**, Azi-Molla-1,-2; **10**, Kok-Tau; **11**, Kara-Bala-Kantemir; **12**, Mechet; **13**, Markovka; **14**, Mirolyubovka; **15**, Rossypnoye; **16**, Nizhneozyornoye; **17**, Chyornaya-1; **18**, Donguz-1, -2, -12; **19**, Berdyanka-2, -3; **20**, Bukobaj-5; **21**, Karagachka; **22**, Kzyl-Saj-2; **23**, Krasnogory-2; **24**, Bekhteyev Gully; **25**, Petropavlovka-1, -2; **26**, Kaltayevo-2, -3; **27**, Yaslav; **28**, Muraptalovo; **29**, Yamangulovo; **30**, Sankubaj, well G-1 (890.1-893.6 m int.); **31**, Rozhykha; **32**, Yelshanka-I; **33**, Dolgy Yar.

that the first of the two forms was first described from the German Muschelkalk. Subsequently, lungfish remains were found within the Triassic beds from the Middle Don (the Don Bend locality), the South Cis-Urals (Donguz-1 and Kaltayevo-2 localities), and over vast areas of the northern Triassic field (Efremov & V'yushkov 1955).

The authors began to study fossil fish from the Triassic of Russia in the mid-sixties. An ample material from over 150 localities was collected, representing Early and Middle Triassic squaliforms, lungfish and actinopterygii from Eastern Europe. The Late Triassic fishes from the region are still unknown. There are over forty localities of the Triassic ichthyofauna in the south of the East European Platform and in the South Cis-Urals (Fig. 1). It was largely this material that provided the basis for revealing the stratigraphic importance of lungfish (Vorobyova & Minikh 1968; Minikh M. G. 1969, 1977), squaliforms and actinopterygii remains (Minikh A. V. 1975, 1985, 1992). Frequent joint finds of fish and tetrapod remains proved to be of much use. The study of both (Ochev *et al.* 1979), combined with informations on other fossils and the data from lithologic (Tverdokhlebov 1966, 1970; Lipatova *et al.* 1965; Lipatova 1967, etc.) and paleomagnetic research (Molostovsky 1983), made it possible to develop unified stratigraphic division schemes for the Triassic of European Russia (Anonymous 1982).

STRATIGRAPHIC ICHTHYOCOMPLEXES

Notwithstanding considerable taxonomic diversity of certain Triassic fish groups, a number of regularities are observed in their evolution, which may be used for stratigraphic purposes. Dipnoans served as the basis for recognition of two major stages, or superichthyocomplexes, changes in the Triassic from the East European Platform and the Cis-Ural deflection: the gnathorhizian and ceratodian ones. The first one has a worlwide distribution from the Late Carboniferous to the Early Triassic. The second one appears in the Early Triassic and exists up to now. It is in the Lower Triassic that their change occur, which is clearly demonstrated by our materials. At the boundary of the Vetlugian and Yarenian, in the Olenekian age, everywhere over the Russian Plate, ceratods appear in the dipnoan fauna, with gnathorhiza still existing. They co-exist during the rather short Fyodorovka time, after which the gnathorhiza vanish. This phenomenon is clearly evident in the Cis-Caspian, within the Bolshoye Bogdo section, as well as in a number of localities from the Moscow and Mezen syneclises. The revealed changes in fossil-fish compositions with time in this region were used for distinguishing the ichthyocomplexes there: two in the Lower (the Vetlugian and Yarenian) and one in the Middle Triassic.

1. The Vetlugian ichthyocomplex is represented by gnathorhiza - *Gnathorhiza triassica triassica* Minich, *Gn. lozovskii* Minich, and hybodusces - *Hybodus spasskiensis* A. Minich. The dominant form here is *Gn. triassica triassica* Minich, which does not occur in any younger deposits. This ichthyocomplex is more complete in the northern Triassic field; a number of stratigraphic groups are recognized within it.

2. The Yarenian ichthyocomplex is subdivided into two groups: the early, the Akhtuba one (with dipnoans: *Gnathorhiza bogdensis* Minich, *Gn. otschevi* Minich, *Gn. triassica baskunchakensis* Minich, *Ceratodus multicristatus* Vorobyova, *C. jechartiensis* Minich, *C. gracilis* Vorobyova; and squaliforms: *Hybodus spasskiensis* A. Minich, *Hybodus maximi* A. Minich) and the later, the Bogdo one (with ceratods: *Ceratodus rectieristatus* Vorobyva, *C. donensis* Vorobyva *et* Minich, *C. multicristatus* Vorobyva, *C. multicristatus lipovensis* Minich, *C. jechartiensis* Minich, *C. kaupi* Agassiz, *C. facetidens* Chabakov; squaliforms: *Hybodus maximi* A. Minich, *H. plicatilis* Agassiz, *Acrodus dunkeri* Auerbach, *Lissodus angulatus* Stensio; and actinopterygii: *Sphaerodus minimus* Agassiz, *Colobodus varius* Giebel).

3. The Middle Triassic ichthyocomplex is also subdivided into two groups of various ages. In the earlier group, the Donguz one, fishes are represented by *Ceratodus gracilis* Vorobyva, *C. bucobaensis* Minich, *C. orenburgensis* Minich,

C. recticristatus Vorobyva, *C. donensis* Vorobyva *et* Minich, *C. jechartiensis* Minich, *Saurichthys dongusensis* A. Minich, *Hybodus otschevi* A. Minich, *Hybodus karagatshkaensis* A. Minich. *Ceratodus recticristatus* Vorobyva, *Hybodus otschevi* A. Minich and *Saurichthys dongusensis* A. Minich are characteristic of the considered group. In the younger, the Bukobaj group, fishes are represented by *Ceratodus bucobaensis* Minich, *C. gracilis* Vorobyva, *C. orenburgensis* Minich, *Saurichthys ultimus* A. Minich, *Hyboduskara gatshkaensis* A. Minich, *Ceratodus bucobaensis* Minich and *Saurichthys ultimus* A. Minich. General information on all the known ichthyofauna localities, within the southern Triassic field, is presented below and its correlative possibilities are revealed.

REVIEW AND CORRELATION OF ICHTHYOFAUNAL LOCALITIES

The Vetlugian ichthyocomplex

Within the Vetlugian series of the Lower Triassic from the South Cis-Urals and the adjacent from the west regions of Obshchy Syrt, fish remains were encountered in several bone-bearing sites. The most ancient of those is Yelshanka-I, a locality 9 km to the south of the town of Buzuluk in Orenburg region. Tooth plate remains belonging to *Gnathorhiza lozovskii* Minich, typical of the Vetlugian ichthyocomplex, were found there in an interlayer of red brown aleurolites within a sand sequence of the Kopanskaya suite. The soundness of this gnathorhiza being assigned to the Kopan level is confirmed by the discoveries of *Tupilakosaurus* sp. vertebra, typically representative of the tupilakosaur group of the vetlugasaur terrestrial vertebrate fauna (Ochev 1992). Another locality, Nizhneozyornoye, is situated in the left wall of a gully, falling into the Ural River near Nizhneozyornoye village, Krasnokholmsk district, Orenburg region. The Early Triassic hybodont shark remains, *Hybodus spasskiensis* A. Minich, were found there in an abandoned-channel suite, represented by a sequence of brown cross-bedded sands with clay and sandstone interlayers with apparent thickness up to 5 m. Chyornaya-I locality is associated with the upper part of the Vetlugian series, the Kzylsaj suite; it is situated along the right bank of the Chyornaya River, 5 km to the south of Krasny Kholm village, Orenburg region. A typical Early Triassic gnathorhiza form, *Gnathorhiza otschevi* Minich, was found there in red-brown sands (10 m). There is another known locality, the one of Mutaptalovo-I, on the right bank of the Bolshoy Yushatyr River near Muraptalovo village, Kyurgazy district in the south of Bashkiria. The section is represented by a sequence of red brown cross-bedded sandstones (over 25 m). In one of the lenticular interlayers was found a fin spine of a squaliform, *Hybodus spasskiensis* A. Minich, typical of the Early Triassic deposits. *Hybodus spasskiensis* A. Minich fin spines were also encountered higher in the section, near Yakutovo village, in similar sandstones containing remains of the Vetlugian tetrapod fauna (*Wetlugasaurus* sp., *Benthosuchus bashkiricus* Otchev). Two other bone-bearing sites from the Kzylsaj suite of the Vetlugian series, containing a typical Vetlugian ichthyocomplex, are known from Buzuluk district, Orenburg region. One of them is Dolgiy Yar locality in the same-named gully falling into the Pogromnaya River (the Samara left tributary), from the left 2.3 km north-west of Logachyovka village. Several well-preserved lungfish tooth plates were found in an interlayer of brown clayey aleurolites within a sequence of cross-bedded sandstones. They belonged to *Gnathorhiza triassica bereznikiensis* Minich, typical of the uppermost layers of the Vetlugian series of the more northerly regions of the East European Platform. The second site, Rozhikha locality, is situated in the mouth of Rozhikha Gully, falling into the Grachyovka River (the Buzuluk left tributary) 1.4 km north of Grachyovka village, Buzuluk district. In the similar rocks of the Kzylsaj suite there, a large tooth plate of *Gnathorhiza otschevi* Minich was found, typically representative of rhe Vetlugian ichthyocomplex. The Vetlugian level of the Triassic section from the Peri-Caspian Depression is penetrated by a substantial number of wells, but with incomplete core selection, lung fish remains (*Gnathorhiza triassica triassica* Minich) were found only in well No. G-1 (Sankubaj), within the 890.1-893.6 m depth interval. These dip-

noan forms are extremely common in Vetlugian deposits, included the area of the northern Triassic field, and may serve as good correlatives of the host beds.

THE YARENIAN ICHTHYOCOMPLEX

Formations of the Yarenian age are widely distributed over the considered regions of the South Cis-Urals and northern Cis-Caspian. Bone remains of terrestrial vertebrates and fishes occur there rather frequently. Taken together, they constitute the basis for determination of the relative geologic ages of the deposits. Within the Peri-Caspian Depression, the Yarenian ichthyocomplex was studied in the Triassic section from the Bolshoye Bogdo Mountain, on the southwestern bank of Baskunchak brine lake (Minikh 1972, 1977). Diverse fish remains from both groups of the Yarenian ichthyocomplex were found there at various levels, in the Akhtuba and Bogdo suites (Fig. 2). Numerous gnathorhiza and ceratod remains were found in the red-bed clayey aleurolites of the Akhtuba suite (bone-bearing site A): *Gnathorhiza triassica baskunchakensis* Minich, *Gn. bogdensis* Minich, *Gn. otschevi* Minich, *Gn.* sp., *Ceratodus multicristatus multicristatus* Vorobyova. Combinations of gnathorhiza and ceratod remains within the Lower Triassic sections are characteristic of the Akhtuba group from the Yarenian ichthyocomplex of the Cis-Caspian. Saurichthian remains (*Saurichthys* sp.) occur within the Akhtuba suite from Bolshoye Bogdo alongside with dipnoans. A typical form of the Akhtuba group, *Gnathorhiza triassica baskunchakensis* Minich, was also encountered at the depth of 553 m in a core from K-6 well (Barkhannaya), drilled between the Ural and the Volga. This part of the Triassic section was assigned to the upper half of the Olenekian stage, according to the ostracode (*Gerdalia triassiana* (Belousova), *G. wetlugensis* Belousova) and charofite (*Porochara triassica* (Saidakovsky), *Auerbachichara achtubensis* Kisilevsky) complexes. The lungfish from this section indicates an Akhtubian age of deposition. In the South Cis-Urals, the early Yarenian (Fyodorovka) group of the Lower Triassic ichthyofauna is only represented in Kyzyl-Say-2 locality (Garyainov & Ochev 1962). In the Burtya River basin (a left tributary of the Ural) near Andreyevka village (Burtinskij district, Orenburg region), in the sand-conglomerate sequence of the Petropavlov-skaya suite, representatives *Gnathorhiza* and *Ceratodus* occur, characteristic of the early Yarenian group (*Gnathorhisa triassica baskunchakensis* Minich and *Ceratodus multicristatus multicristatus* Vorobyova). In the suite section they are associated with hybodont sharks remains, *Hybodus spasskiensis* A. Minich. Thus, the presence of Gnathorizds and Ceratodids in the Lower Triassic sections makes it possible to correlate the Akhtuba suite of the Peri-Caspian Depression with the lowermost part of the Petropavlovka suite of the South Cis-Urals in the reference section along the Kyzyl-Say Gully. Two explanations may be offered for the lack of representativeness of this fish-group in the suite stratotype section near Petropavlovka village. The first one seems to be optimistic: the discoveries are waiting ahead. The second one runs as follows: either this part of the section is absent from the stratotype or the conditions for fish burial were unfavourable near Petropavlovka at that time.

The late Yarenian (Gamskaya) group of the Early Triassic ichthyofauna is reasonably completely represented in the South Cis-Urals and in the adjacent western region of the East European Platform. First of all, let us mention the availability of a purely ceratod dipnoan association in the Petropavlovka suite stratotype (Tverdokhlebov 1967a). This is situated on the bank of the Sakmara (Fig. 1), in the vicinity of Petropavlovka village, Sakmara district, Orenburg region. It is mainly built (Fig. 2) of greyish brown sandstones with aleurolite and clay interlayers of a total thickness up to 250 m. Dipnoan remains (*Ceratodus multicristatus lipovensis* Minich and *C. jechartiensis* Minich) were found there at various levels (Petropavlovka-1 and -2 localities). These fish widely occur in the late Yarenian deposits of the East European Platform. *Ceratodus multicristatus lipovensis* Minich tooth plates were also encountered (Fig. 3) in the Petropavlovka suite-developed along the Donguz River (Donguz-9 locality) near Mescheryakovka village, Sol-Iletsk district, Orenburg region, in Bekhteyev Gully within the

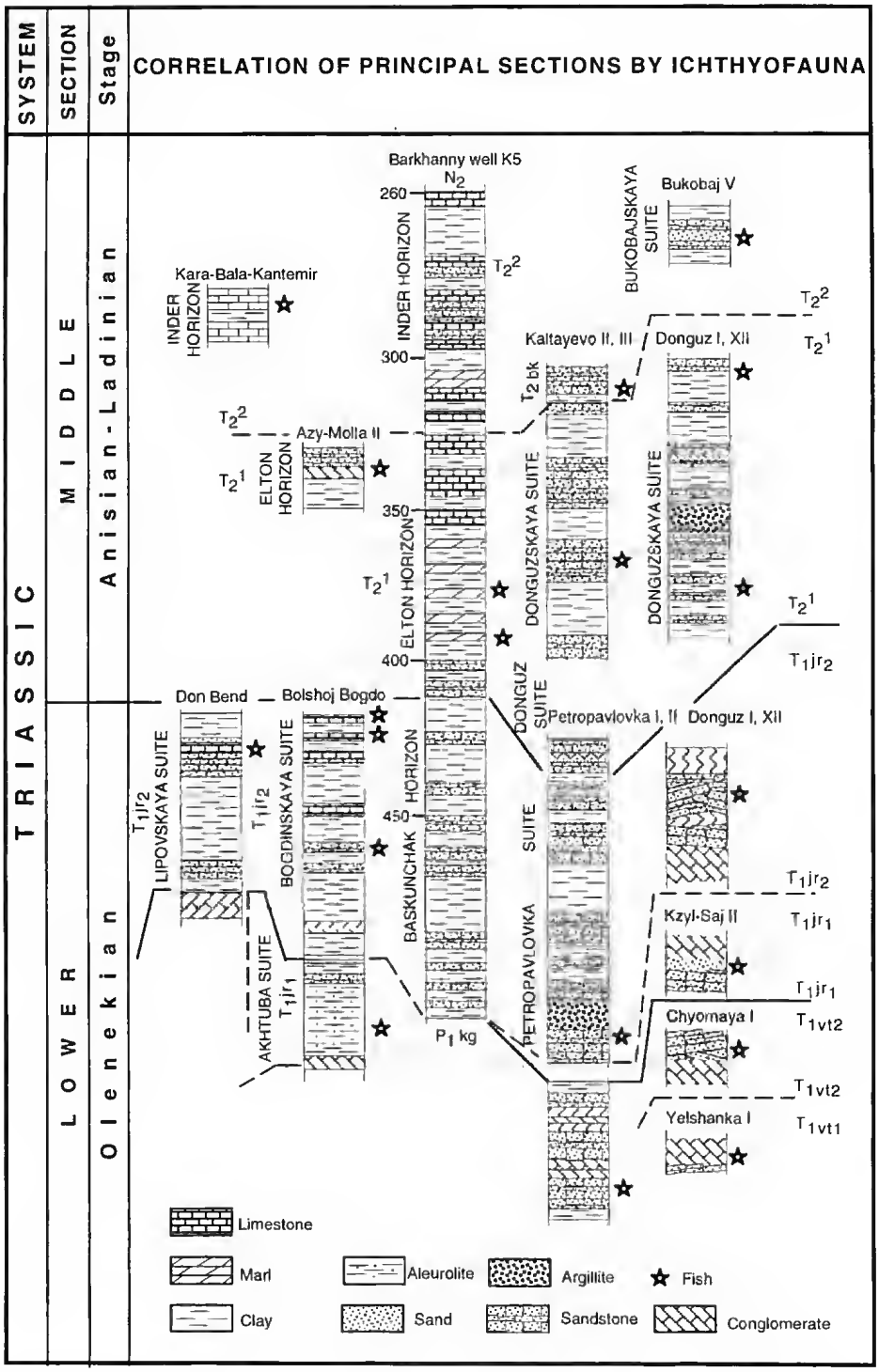

FIG. 2. — Correlation of the Triassic sections from the northern Cis-Caspian and southern Cis-Urals regions according to ichthyofauna.

Ural-Sakmara watershed, and in the vicinity of Yazlav Farm, Kyurgazy district, Bashkiria. There is a major Triassic vertebrates locality, Rossypnoye, to the west of the Cis-Ural deflection, in the territory of Obshchiy Syrt (Efremov & V'yushkov 1955). It is located in the right slope of Mayachnaya Gully, opened from the right into the Ural valley 1.0 km to the north-east of Rossypnoye village, Ilekskij district, Orenburg region. Ceratod tooth plates *Ceratodus recticristatus* Minich (Fig. 3) occur here alongside with parotosuchian fauna tetrapod remains, in red clays.

An even richer locality of Early Triassic vertebrates, the Don Bend (Rykov & Ochev 1966), is known from the south-eastern slope of the Voronezh antecline dislocations. It is situated (Fig. 1) in a large bend of the Don, north of Sirotininskaya village, in Lipovskij Gully (a Don right tributary). Diverse fish remains occur there in the upper, sand-conglomerate portion of the Lipovskaya suite, together with the parotosuchian tetrapod fauna remains. Among fish, dipnoans are found there; *Ceratodus multicristatus lipovensis* Minich, *C. jechartiensis* Minich and *C. donensis* Vorobyova *et* Minich; sharks *Hybodus maximi* A. Minich, *Lissodus angulatus* Stensio, actinopterygii *Saurichthys* sp., and other, forms of squaliform and actinopterygian fish that are not decribed yet. On the whole, according to the composition of fossils encountered there, the Don Bend locality belongs to the Late Yarenian (Lipovskaya) group of the Early Triassic ichthyofauna, and may be correlated by fish with most of the Petropavlovka suite from Obshchiy Syrt and from the Cis-Ural Deflection; through these, it may also be correlated with the Gamskaya suite from Safonovsky Deflection of Mezen syneclise. It is interesting to compare *Ceratodus donensis* Vorobyova *et* Minich, very common in the Lipovskaya suite and described by the Don Bend material, with the Triassic ceratodes known from all over the world. Among the European forms, *C. priscus* Fraas from the Lower Triassic of Schwarzwald (medium mottled sandstones) seems to be the most similar one. This allows us to correlate, in a first approximation, the Lower Triassic dipnoan bearing beds from the East European and West European Platforms.

Within the Peri-Caspian Depression, the Late Yarenian (Bogdo) group of the Early Triassic ichthyofauna is most clearly seen in the Bogdo suite section (Fig. 2), from the Bolshoye Bogdo Mountain (bone-bearing site B). Fish remains are represented there by dipnoans (*Ceratodus multicristatus lipovensis* Minich, *Ceratodus facetidens* Chabakov and *Ceratodus* ex. gr. *kaupi* Agassiz) and squaliforms (*Hybodus plicatilis* Agassiz and *Acrodus dunkeri* Auerbach). Actinopterygii are represented by perleidids (*Colobodus varius* Giebel and *Sphaerodus minimus* Agassiz) and saurichtiids (*Saurichthys apicalis* Agassiz and *Saurichthys* sp.).

Evolutionary levels identities, and similarities in a number of lungfish, squaliforms and actinopterygians from the single late Yarenian group of the Early Triassic ichthyofauna within the Cis-Caspian Bogdo section and those from the Triassic section of the Don Bend (*Ceratodus multicristatus lipovensis* Minich, *Lissodus* sp. and *Saurichthys* sp.), make it possible to correlate with certainty the Bogdo suite with the Lipovskaya suite of the Middle Don, the Petropavlovka suite of the south-eastern slope of the Volga-Ural antecline and the south of the Cis-Ural deflection. The presence in the Bogdo group of ceratods, *Ceratodus kaupi* Agassiz, very common in the Middle Triassic Muschelkalk of the German basin implies, in its turn, probable paleogeographic and ichthyofaunal connections between the Bogdo and German marine sedimentation basins towards the end of the Early Triassic. Such a connection between the Peri-Caspian and North German Depressions might be accomplished through the Cis-Caucasian marginal deflection, the system of the Dnieper-Donets depressions, Pripyat Deflection and Polish-Lithuanian syncline. At the end of the Early Triassic, a lot of interconnected freshened semi-marine basins existed all over that region, which might provide the exchange of brackish faunas.

The Middle Triassic ichthyocomplex

In the territory of European Russia, the Middle Triassic ichthyofauna was first discovered and described from the South Cis-Urals (Vorobyova & Minikh 1968). It comes from the Donguz and Bukobaj suites (Tverdokhlebov 1967b) and is

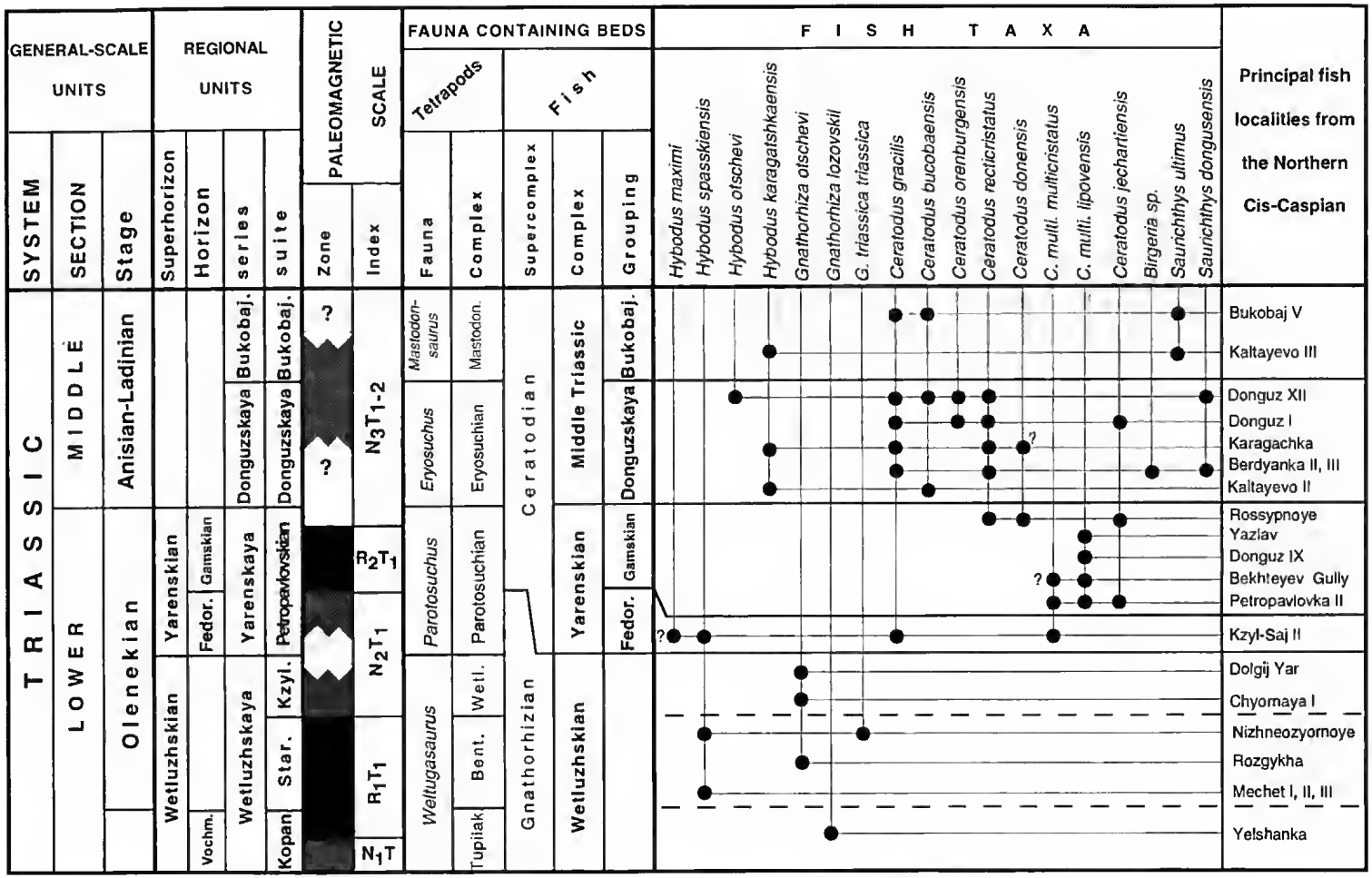

FIG. 3. — Ichthyofauna distribution within the sections of the Triassic from the southern Cis-Urals regions.

known from the faunas of a number of localities, where it is often encountered together with the remains of eriosuchian and mastodonsaurian terrestrial vertebrate faunas (Ochev 1992). The principal localities of the Middle Triassic ichthyofauna are associated with type and reference sections of both suites. The Donguz suite stratotype is located along the Donguz River (left tributary of the Ural) near Perovka village, Sol-Iletsk district, Orenburg region. The section is generally composed of variegated aleuro-clayey and arenaceous rocks up to 150 m thick. In the middle part of the suite, in the conglomerate-like interlayers among variegated aleurolites and clays of the Donguz-I locality (Figs 1-3), lung fish tooth plates were discovered (*Ceratodus gracilis* Vorobyova, *C. rectieristatus* Vorobyova, *C. orenburgensis* Minich and *C. jechartiensis* Minich). The latter forms, although quite common in the upper layers of the Lower Triassic, are rather rare in the Middle Triassic. About 75 m higher in the section of the Donguz suite, in the Donguz-12 locality in a lens of unsorted sandy-aleurite rocks together with bones of tetrapod eriosuchian fauna and tooth plates of ceratods (*Ceratodus gracilis* Vorobyova, *C. rectieristatus* Vorobyova, *C. orenburgensis* Minich and *C. bucu-baensis* Minich), some other fossils were found: hybodontid fin and head spines (*Hybodus otschevi* A. Minich), teeth of *Lissodus angulatus* Stensio, teeth of new squaliform genera and species (their descriptions are being prepared for publication) and actinopterygian jaws (*Saurichthys dongusensis* A. Minich). Almost the same set of taxa occurs among the lungfish and squaliform remains, from a number of other vertebrate localities, at various levels of the Donguz suite of the South Cis-Urals. These are Berdyanka-2, Berdyanka-3, Karagachka, Kaltayevo-2 localities (Figs 1-3). Fin pines of yet another *Hybodus* species were found in the latter two ones: *Hybodus karagatshkaensis* A. Minich, typical of the whole of the Middle Triassic ichthyocomplex.

Thus, the Donguz group of the Middle Triassic ichthyofauna clearly stands apart from the above considered Early Triassic ones, because of the new dipnoan species appearing within the sections (*Ceratodus gracilis* Vorobyova, *C. bucobaensis* Minich), new squaliforms (*Hybodus karagatshkaensis* A. Minich, *H. otchevi* A. Minich) and actinopferygians (*Saurichthys dongusensis* A. Minich). All these forms may be regarded as typical of the Middle Triassic ichthyocomplex on the whole. The combination of these forms with those known from the Early Triassic deposits (*Ceratodus rectieristatus* Vorobyova and *C. jechartiensis* Minich) makes it possible to separate the Donguz group both from the earlier and from the younger groups of the Triassic ichthyofauna.

Along with fish remains in the Donguz suite of the South Cis-Urals, the remains of eriosuchian fauna terrestrial vertebrates occur, which correlate with the Ladinian tetrapod association from the uppermost Muschelkalk and lower Keuper of Germany, according to common plagiosaur genera (*Plagiosternum* and *Plagioscutum*).

The Donguz suite correlates with the Elton suite established in the northern Cis-Caspian, according to the ichthyofauna. The section of the Middle Triassic and its ichthyofauna were studied there (Fig. 4) from the cores of several reference and parametric wells and from the natural outcrops on the north-eastern shore of Inder Lake. The lake is situated in the left-bank region of the Ural, south-east of Inderborsky settlement, Gurjev region, Kazakhstan. A rather complete section of the Triassic, typical of the central parts of the Peri-Caspian Depression, is known there on the slopes of the Kok-Tau Range and along the lake shores. The Early Triassic Cis-Caspian series are represented in the Inder section by the basal red-bed clayey sequence (over 200 m). The Middle Triassic is represented by the Elton (a red-bed arenaceous-conglomerate sequence, up to 110 m and an arenaceous-clayey one up to 60 m) and Inder suites (grey-coloured limestone-clayey sequences about 250 m). The Late Triassic variegated sandstone sequence lies above them (up to 100 m), the Masteksaj horizon (Anonymous 1982).

The Lower/Middle Triassic boundary was previously drawn (Ochev & Smagin 1974) within the Elton suite, between the basal sandy-conglomerate and the red-bed sandy-clayey sequences. Our point of view regarding this problem was determined after the discovery of typical Middle Triassic ichthyofauna remains in the

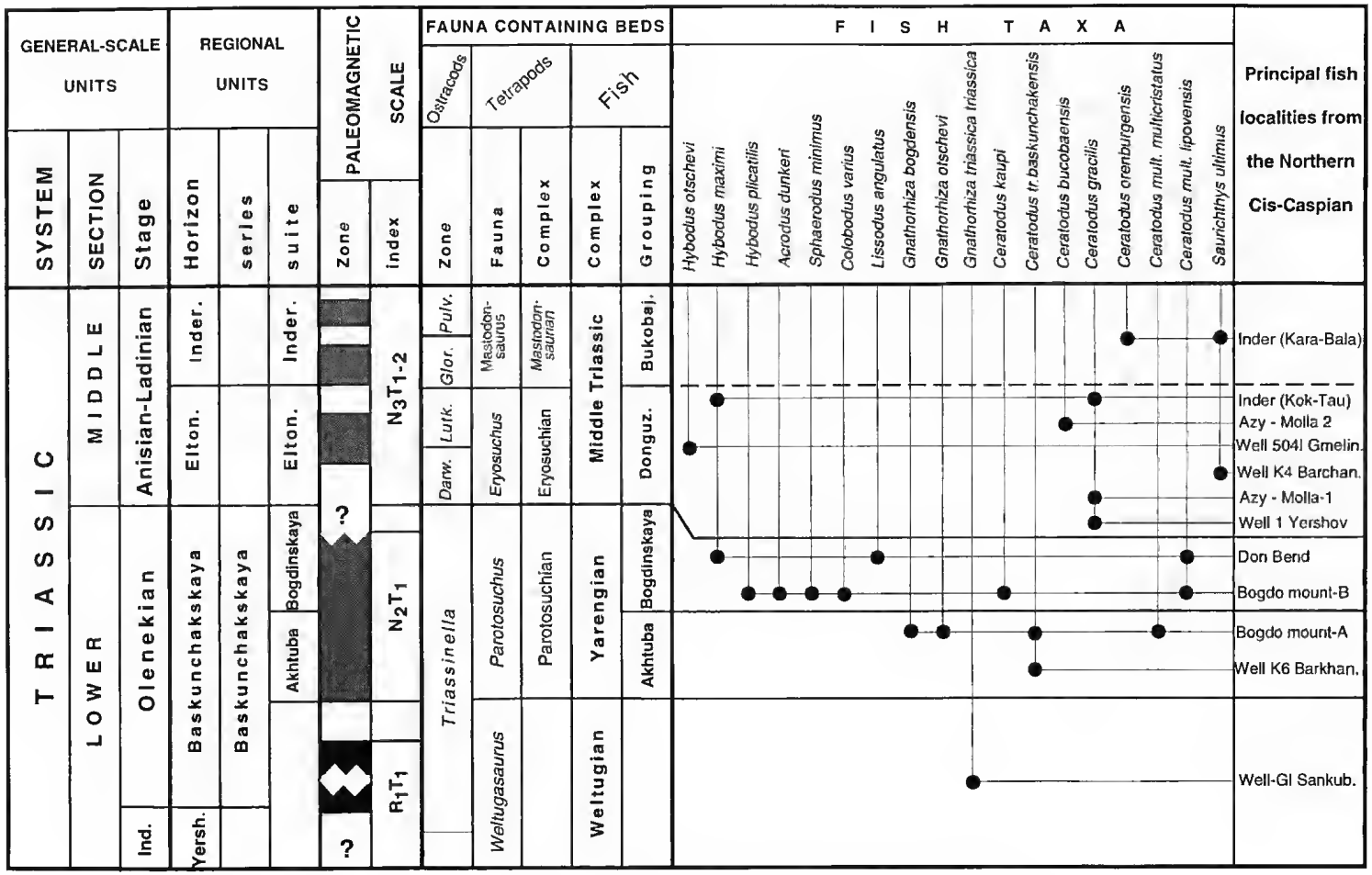

Fig. 4. — Ichthyofauna distribution within the sections of the Triassic from the northern Cis-Caspian region.

sand-conglomerate sequence of the Elton suite. Lungfish tooth plates (*Ceratodus gracilis* Vorobyova) and undefinable tetrapod bone fragments were found there in the Kok-Tau and Azi-Molla-1 locations. This ceratod species is known as a component of the Middle Triassic (Donguz) ichthyocomplex from the South Cis-Urals. In the northern Cis-Caspian, this species is also found in some cores from the wells penetrating the Middle Triassic sections (the age was determined from ostracodes and charophytes). These are the sections of the Yuzhno-Yershovskaya-1 well (931.0-934.0 m interval), Barkhanny K-5 well (379.0-385.9 m and 385.9-392.9 m intervals) and Zhundykuduk-46 well (490 m depth). Besides ceratods, some sections contain the remains of hybodont sharks typical of the Donguz fish-group (*Hybodus otschevi* A. Minich; Gmelinka 5041-C well, 1521-1526 m interval) and new species of the shark genus *Lissodus* (Barkhanny K-4 well; 361.5-365.5 m interval).

The presented data on ichthyofauna distributions within the Middle Triassic deposits, confirm that *Ceratodus gracilis* Vorobyova belongs to the Middle Triassic ichthyofauna of the Donguz group; its taxonomic composition is rather stable within the whole of the southern field of the Triassic development in European Russia. On the basis of these lungfish discoveries, the age of the basal sandy-conglomerate sequence of the Elton suite, from the Inder Triassic section, may be defined as the Middle Triassic.

The younger, Bukobaj group of the Middle Triassic ichthyofauna, from the South Cis-Urals, is known from the stratotype section of the Bukobaj suite in Bukobaj-5 locality. It is situated in Bukobaj Gully falling in the Berdyanka river (left tributary of the Ural) from the right, upstream Belyayevka village, Sol-Iletsk district, Orenburg region. Within the light-grey sands and sandstones of this area, lungfish tooth plates were discovered (*Ceratodus gracilis* Vorobyova and *C. bucobaensis* Minich), as well as the remains of saurichthiid *Saurichthys ultimus* A. Minich, typical of the Bukobaj fish group. Some mastodonsaur tetrapod fauna remains were also found there. The Bukobaj suite comprised also the deposits, outcropping along the right bank of the Bolshoj Yushatyr river near Starokaltayevo village (Efremov & V'yushkov 1955). In the Kaltayevo-3 location there, within the grey sandstones, besides tetrapods *Mastodonsaurus torvus* Konzhukova and others, squaliforms were found, *Hybodus karagatshkaensis* A. Minich, which occurs as early as at the Donguz level, and the latest of the saurichthiids known from the region, *Saurichthys ultimus* A. Minich, similar in their morphologic features to saurichthys from the Ladinian stage of Turkey (Minikh A. V. 1992).

In the northern Cis-Caspian, the Inder suite is correlated to the Bukobaj suite from the South Cis-Urals by tetrapod and fish faunas. A vertebrate locality, Kara-Bala-Kantemir, was discovered in the suite stratotype in the vicinity of Inder Lake (Ochev & Smagin 1974). This is situated on the north-eastern shore of Inder Lake on the hill top, 200 m to the south of Kara-Bala-Kantemir graves (masars). There, in the greyish-green clays of the Inder suite, along with the bones of mastodonsaur fauna tetrapods, ostracodes and charae (Lipatova *et al.* 1969), the remains were found that are typically representatives of the Middle Triassic Bukobaj ichthyofaunal group: ceratodontid tooth plates (*Ceratodus orenburgensis* Minich) and a cartilaginous ganoid (*Saurichthys ultimus* A. Minich).

CONCLUSION

The wide distribution of ichthyofaunas, similar in composition, in the south-east of the Russian Plate and in the northern Cis-Caspian, as well as the general succession in its change with time, indicate the unity of depositional basins in the Triassic, all over the considered territory. Such fishes as hyboduses, ceratods and saurichthii prove to be very cosmopolitan. They are widespread and common in the Triassic deposits from practically all the continents of the globe (Minikh 1977; Minikh A. V. 1982). This may be used for solving the important problems of distant inter-regional and intercontinental correlations of marine, semi-marine and continental Triassic deposits.

Acknowledgments
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An essay on regional geology and stratigraphy of the Upper Cretaceous deposits of southern Urals territories

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ABSTRACT

The Turgay region is considered as the north-eastern border of the Peri-Tethyan basins during the Cretaceous. This area contained elements of each area's faunas: the relatively warm Peri-Tethys faunas with the cooler West Siberia faunas. Cretaceous deposits are found throughout the southern Urals, especially in the western and southern Primugodzharie, Aktyubinskian Priuralie, and Pri-Irgizsky areas. Cretaceous deposirs are covered by Cenozoic rocks, shown from well cores of the south-eastern border of Mugodzhar mountains, Turgay and northern PriAralie. The Lower Cretaceous in the southern Urals was predominately continental. In the western Primugodzharie and Aktyubinskian Priuralie region, marine sediments of Neocomian, Aptian and Albian age were deposited. Red continental sedimentary rocks were deposited during the Neocomian. Coal and bauxite were deposited during Aptian and Albian. The Lower Cretaceous boundary was marked by a marine regression, while the Aptian and late Albian-early Cenomanian are characterized by extensive continental rocks on the entire territory, with the exception of the Turgay region. A widespread marine transgression is evident during the Cenomanian.

KEY WORDS
stratigraphy, correlation, Cretaceous, South Ural, paleontology.

This transgression influenced the sedimentation in the southern Urals, East European, Scythian, Turan and West Siberian platforms. Upper Cretaceous was dominated by shallow marine facies, coastal and shore deposits. Marine transgression continued until late Maastrichtian. The end of the Late Maastrichtian was characterized by the appearance of very shallow water and lagoonal regressive facies. The Cretaceous/Paleogene boundary was marked by a pause of sedimentation with erosional unconformities in the boundary between the Maastrichtian and Danian. Foraminifera, radiolaria, belemnites, selachians, mollusca, pollen, and spore reveal the timing of events and suggest the paleoenvironment of this region during the Upper Cretaceous.

RÉSUMÉ

La région de Turgay représente la bordure nord-orientale de l'ensemble Péri-Téthysien au Crétacé. Cette région comprend des éléments des diverses provinces fauniques; des faunes Péri-Téthysiennes relativement chaudes et des faunes froides Sibériennes. Des dépôts Crétacés existent partout dans l'Oural méridional, et particulièrement dans les zones occidentales et méridionales de Prémugodzharie, du PériOural Aktyubinskien, et les zones de Péri-Irgizsky. Des forages de la bordure sud-orientale des monts Mugodzhar, Turgay et de PétiAralie septentrionale ont révélé que les sédiments Crétacés sont recouverts de roches Cénozoïques. Le Crétacé inférieur de l'Oural septentrional est essentiellement continental. Dans le Primugodzharie occidental et la région du PériOural d'Aktyubinsk, des sédiments marins du Néocomien, de l'Aptien et de l'Albien existent. Des roches sédimentaires continentales rouges se sont déposées au cours du Néocomien, puis du charbon et de la bauxite à l'Aptien et à l'Albien. La limite inférieure du Crétacé est marquée par une régression marine alors que l'Aptien et l'Albien supérieur-Cénomanien inférieur est caractérisé par une grande extension des dépôts continentaux, sur l'ensemble du territoire, sauf dans la région de Turgay. Une large transgression marine se manifeste au Cénomanien. Cette transgression a influencé la sédimentation dans l'Oural méridional, l'Europe orientale, et les plates-formes Scythienne, de Turan et de Sibérie occidentale. Le Crétacé supérieur fut dominé par des faciès de mer peu profonde, et des dépôts côtiers et de rivage. La transgression marine a continué jusqu'au Maastrichtien supérieur qui s'est terminé par des faciès très peu profonds et régressifs lagunaires. La limite Crétacé/Paléogène fut marquée par une pause de sédimentation et des discontinuités érosives à la limite Maastrichtien-Danien. Les foraminifères, radiolaires, bélemnites, sélachians, mollusques, pollens, et spores indiquent la chronologie des événements et révèlent les types de paléoenvironment de cette région au cours du Crétacé.

MOTS CLÉS
stratigraphie,
corrélation,
Crétacé,
Oural méridional,
paléontologie.

INTRODUCTION

Tectonic activity in the Uralian mobile belt ceased at the beginning of the Mesozoic, completing the suturing of the Russian platform and West Siberian plate. A new tectonic regime began to evolve. During the Late Jurassic-Lower Paleogene, the Uralian epihercynian platform was generally uplifted. Mountain building coupled with erosion were the predominate mechanisms during this time. Thin beds of continental sediments were accumulating in the surrounding basins.

During the early part of the Cretaceous, the northern portion of the Urals downwarped at a faster rate. A transgressive cycle flooded this region with northern boreal waters. This epicontinental sea was a mixture of waters from the Polar, North Atlantic and North Pacific paleobasins. The southern portion of the basin was not invaded, as there is only evidence of continental sedimentation in local depressions.

During the later part of the Cretaceous, the southern portion of West Siberia was tectonically downwarped allowing the transgressions to fully invade the Russian Platform, West Siberian Basin and Peri-Tethyan basins of the Turanian Plate. The Turgay trough allowed the north-western portion of central Asia and north-western Kazakhstan to experience marine conditions (Papulov 1974).

This connection influenced the microbiota of West Siberian during the Late Cretaceous. Elements of the Tethyan fauna are found in semi-isolated marine basins. Components of foraminifera, radiolarian and mollusca of the West Siberian region can be correlated to the fauna of the Peri-Tethyan region. The Turgay Trough records this mixed fauna.

The Turgay Trough is situated between the eastern slope of southern part of the Ural Mountains and the Kazakh Shield. The northern Turgay area has well preserved Upper Cretaceous assemblages and is a reference section for foraminifera and radiolaria for Cenomanian, Conacian, Santonian, Campanian, and Maastrichtian. Upwarping in the north near Kustanay City, Kazakhstan, was the southern limit between the West Siberian basin. South of this area marked the area of the Peri-Tethyan basins, where arctic-boreal waters of West Siberia mixed with the warm waters of the Peri-Tethys. This basin has faunal representatives of the warm waters of Peri-Tethyan basins with the arctic-boreal faunas of West Siberian basins. These assemblages are key to understand the interaction of the West Siberian, European, and Peri-Tethyan basins. Understanding the biostratigraphy in the Cretaceous of the southern Urals will help to correlate timing of events of the Peri-Tethys and West Siberia.

Fig. 1. — Location map. **1a**, Or'-Ilek Hills area; **1b**, Mugodzhar Mountains; **1c**, eastern Mugodzhar Mountains; **2a**, Aktyubinskian Priuralie; **2b**, western Primugodzharie; **2c**, southern Primugodzharie; **3a**, north-eastern Usturt; **3b**, northern PriAralie; **4a**, western side of Turgay Trough; **4b**, south-western Turgay; **4c**, Turgay Trough; **4d**, eastern side of Turgay Trough.

STUDY AREA

This area encompasses a vast region (Fig. 1), with few outcrops. The termination of the Urals in the south is bordered by the Or'-Ilek Hills and Mugodzhar Mountains. The Or'-Ilek Hills (altitude 30-509 m) represents the divide between the Or' and Ilek Rivers basins. The Or'-Ilek Hills are approximately 100 km wide, ranging from Orsk City on the east to Aktyubinsk City on the west; and 200 km long, extending from the Ural River Valley on the north, to Kandagach in the

south. The Mugodzhar Mountains are low mountains south of the Or' River. The Mugodzhar Mountains consist in several ranges and groups of low mountains and hills. The highest peaks are approximately 650 meters. The Shoshkakolian Range (altitude 274-408 m) is the most southern extension of the Mugodzharian Range.

The Poduralian area (Embian Plateau) is south-west of the Or'-Ilek Hills, Mugodzhar Mountains and Shoshkakolian Range. The Embian Plateau is an erosional surface draining toward the PriCaspian lowland. The East Mugodzharian plateau is north-east of the Mugodzhar mountains and south of the Or' River. The East Mugodzharian plateau drains toward the Turgay plateau.

The south-western portion is formed by the north-eastern frame of the Ustyurt Plateau (100-200 m) and the Shagray Plateau (100-150 m) and the Shoshkakolian Range in the south. The PriAralian Plain (150 m) is the territory north of Aral Lake. It contains the sandy Bolshie, Malye Barsuki, Barshakum and PriAralian Karakum Deserts. The eastern portion of Turgay Trough is the Turgay Plateau. It is spread between the massifs of the southern Ural mountains, east of the Mugodzhar Mountains and west of the low lying Kazakh Melkosopochnik Hills, Central Kazakh. The length is around 800 km (north-south), and width (east-west) is 300-450 km.

The south-western part of Turgay Plateau, adjoining to the East Mugodzhar Plateau, is called the Pri-Irgiz Plain (150 m). The western part of the Turgay plain is the eastern border of Zauralian Plateau (altitude 250-350 m). The Turgay Plain in the north is called the Kustanay Plain (altitude 170-220 m); the central part is called the Aday-Ul'kayak plateau (altitude 220-300 m); the east is called the East Turgay Plateau (200-400 m) and the south is called the South Turgay Plain (altitude 150-180 m) (Miletsky, 1981; Ozhiganov 1964; Zakharov & Udri 1971; Vereschagin *et al.* 1975; Gerasimov *et al.* 1968; Yanshin 1953).

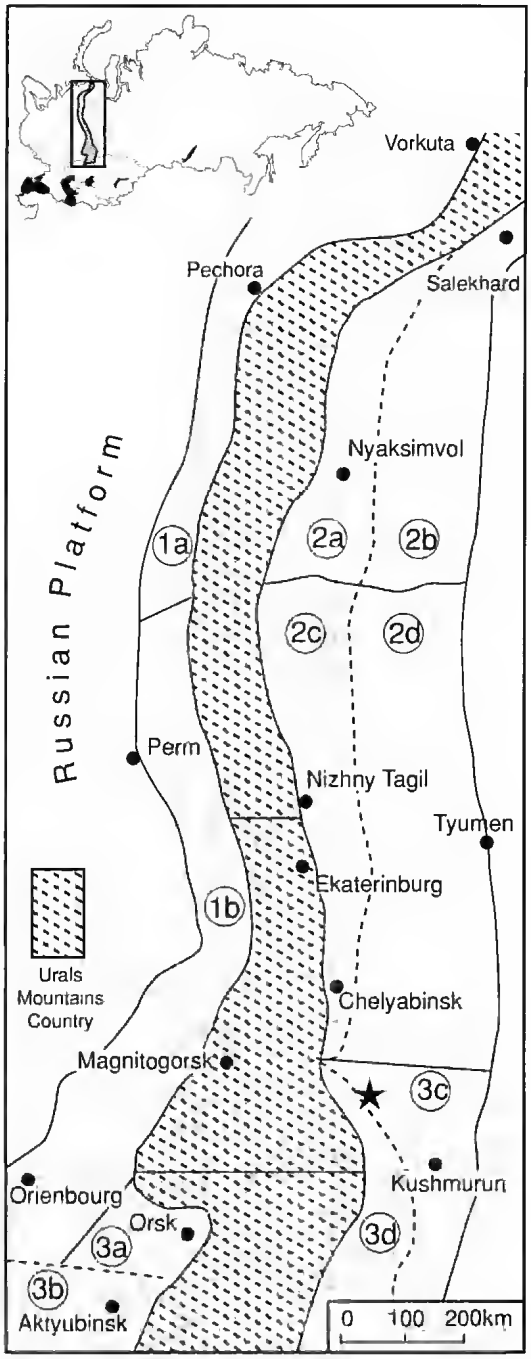

Fig. 2. — Scheme of structural-facies subdivision of the Urals during the Cretaceous. **1**, Preduralie; **1a**, Polar, Pripolar and northern Preduralie; **1b**, middle and southern. **2**, Zauralie; **2a**, Pripolar and north-western Zauralie; **2b**, Pripolar and north; **2c**, middle and south-west; **2d**, middle and south. **3**, Predmugodzharie; **3a**, Orsky area; **3b**, Khobdinsky, Ileksky, and Zhurunsky area; **3c**, north-west Turgay; **3d**, north-east Turgay.

STRUCTURAL OVERVIEW OF AREA

The Urals are divided into areas that reflect dif-

ferences in structure and depositional environments. The Russians refer to these as structural-facies divisions. Figure 2 shows the general scheme of the structural-facies divisions of the Urals during the Creraceous. This paper emphasizes the Upper Cretaceous events that occurred in the southern termination of the Urals and adjacent territories (Fig. 2; 3a-d))

The southern Urals is subdivided into four main structural-facial zones (Fig. 1): (1) southern termination of the Ural Zone; (2) western adjoining plains or Primugodzharie and north-eastern Pricaspian Zones; (3) southern adjoining plains or PriAralie and north-eastern Ustyurt Zones; and (4) eastern adjoining plains or Turgay Zone. The Or'-Ilek Hills area corresponds to the Central Uralian anticlinorium and includes the area west of the Kosisteksky region (the southern continuation of the Sakmarian Zone of southern Urals), and the area east of the Kempirsaysky region (continuarion of South Uralian Zone).

The Mugodzhar Mountain area (Fig. 1: 1a-c) includes the southern terminations of three widespread Uralian regional structural units: Tagil-Magnitogorskian synclinorium, East Uralian anticlinorium, and portions of the Zauralian anticlinorium.

The Primugdozharie Zone (Fig. 1: 2a) includes the area west of the Mugodzhar Mountains and is referred to as the Aktyubinskian Priuralie area. This corresponds to Aktyubinskian pericline trough of the Ural fold system, which is partly covered by Mesozoic-Cenozoic blanket deposits. The western Primugodzharie (Fig. 1: 2b) is a broad belt west of the Mugodzhar Mountains. This area corresponds to the Kempirsayskian Zone of Central-Uralian anticlinorium and to the eastern border of Pri-Caspian depression of East European platform. The western portion of the western Primugodzharie and southern Primugodzharie areas are similar to the east-north-eastern parts of the PriCaspian lowland area. In the southwest area of the Mugodzhar Mountains, the region referred to the southern Primugodzharie is located (Fig. 1: 2c). The Shoshkakolian Range is located in this region and is considered as a continuation of the Mugodzhar Mountains, which is equivalent to the eastern part of south Emba area (Zakharov & Udris 1971; Sobetski 1982).

The PriAtalie Zone is located in the southern adjoining plains (Fig. 1: 3a, b) The western portion is referred to the north-eastern Ustyurt region. It is formed by horizontally bedded Neogene, Oligocene, Eocene, and Cretaceous deposits. This area is equivalent to the eastern part of the PriUstyurt area. The northern PriAralie adjoins the North Aral Lake and is characterized by a Paleozoic geosyncline basement and thick Mesozoic-Cenozoic sedimentary cover.

The Turgay zone (Fig. 1: 4a-c) includes the Turgay Plateau from the West Siberian plain in the north to the PriAralian Karakum Desert in the south. There are several fold systems identified in this area, including the Kustanayan synclinorium, Ubaganian anticlinorium, Aksuatskian synclinorium, and Esilskian synclinorium. In the eastern slope of the Urals, the Zauralian anticlinorium is the western border of the Turgay trough. The south-western Turgay region is situated between the Mugodzhar mountains and the northern PriAralie. This area has a deeply folded basement with a well developed sediment cover. In the southern portion is the boundary between the Central Kazakhstan fold system, PreCambrian and Early Paleozoic rocks outcrop in the Ulytauskian anticlinorium and form the eastern frame of Turgay trough. This region is referred to as the eastern border of Turgay trough or eastern Turgay. These boundaries are well documented in the literature (Miletsky 1981; Ozhiganov 1964; Zakharov & Udris 1971; Yanshin 1971; Vereschagin *et al.* 1975; Moskvin 1986, 1987; Naidin *et al.* 1986; Papulov 1974).

STRATIGRAPHY OF CRETACEOUS DEPOSITS

CENOMANIAN (Figs 3-5)

During the Cenomanian, the southern Urals range from continental to marine. Continental and semi-marine (lagoonal lacustrine) rocks of upper Albian to lower Cenomanian (Alrykudukskaya Formation). Coastal marine rocks are characteristic of the Nogaytinskaya Formation (Primugodzharie and PriAralie) in the Primugodzharie and PriAralie regions. Semi-marine and continental rocks of Cenomanian-

Turonian age (Shetiregizskaya and Novokozyrevskaya Formation) are located in Turgay. Lower-middle Cenomanian coastal marine deposits are found in the western Primugodzharie and Aktyubinskian Priuralie. Upper Cenomanian deposits in the western areas are absent.

The late Albian - early Cenomanian Altykudukskaya Formation occurs on marine deposits of the Aptian-Albian Bogdanovskaya Formation in the Aktyubinskian Priuralie region. The Altykudukskaya Formation in western Primugodzharie and Or'-Ilek Hills is unconformably laid on Paleozoic rocks. In the southern Primugodzharie, north-eastern Ustyurt and northern PriAralie, the Altykuduskaya Formation lies on the continental deposits of the Aptian-Albian Karashataukskaya and Kysylshenskaya Formation. In the western area the Altykudukskaya Formation has surface outcrops. Throughout the rest of the region, the depth has been determined by boreholes (Zhelezko & Segedin 1972; Miletsky 1981).

The Altykudukskaya Formation mainly consists of white to yellow, siltstones to conglomerates, unconsolidated clays to gravel, with sandy concretions and plant debris. Two sections can be recognized. The lower unit contains light grey to yellow-grey, poorly sorted, quartz rich sands in horizontal or slanting beds. Gravel and pebbles are found in the sand layers with kaolinite. The total thickness of the lower unit ranges from 20-120 m. Spores and pollen (SPA IV.1) from early Cenomanian age are found in the lower units.

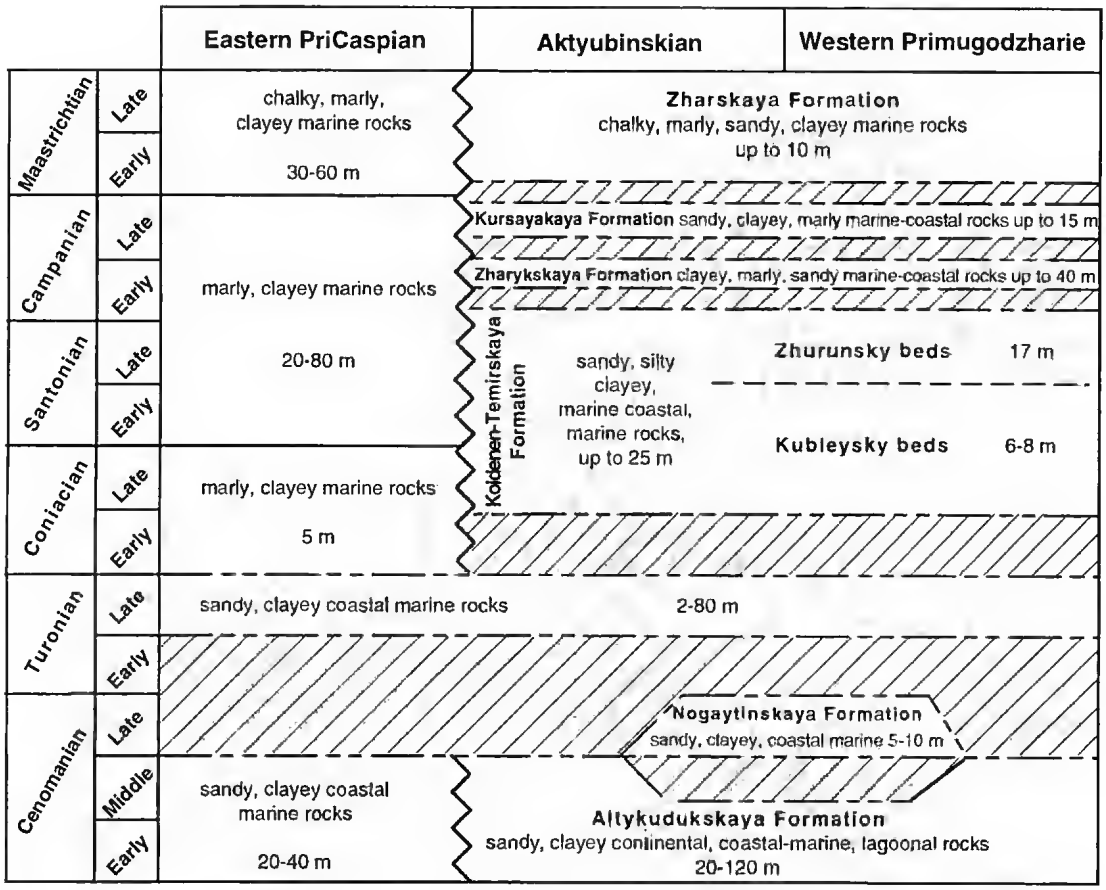

Fig. 3. — Correlation of Upper Cretaceous deposits of eastern PriCaspian, Aktyubinskian Priuralie, and western Primugodzharie.

The upper portion of the Altykudukskaya Formation is found in the western areas and has well preserved selachia (shark teeth) which are from the *Palaeoanacorax volgensis* Zone of Albian-early Cenomanian age (Zhelezko & Segedin 1972). Flora from the Koldenen-Temirskian paleoflora (LFA 1) of late Albian-Cenomanian age is found in sandy horizons (Shilin 1986).

In the eastern PriCaspian region, transgressive Cenomanian coastal and deeper marine deposits are found on continental Albian rocks. The Cenomanian rocks in this area consist of yellow-grey, green-grey, yellow, quartz rich glauconite sands, grey sandy clays, and sandstones. Ammonites of the *Kamaroites grossouvrei* Zone (early-middle Cenomanian); selachians of the *Palaeoanacorax obliquus* Zone (early-middle Cenomanian); mollusca of *Oxytoma pectinata* Zone (early Cenomanian); and foraminifers of the *Gavelinella cenomanica* Zone (early-middle Cenomanian) are found. The total thickness ranges from 20-40 m (Nevesskaya 1985; Azbel & Grigyalis 1991).

The western Primugodzharie, transgressive deposits of marine quartz sands, siltstones and clayey siltstones of the Nogaytinskaya Formation overlies continental deposits of the Altykudukskaya Formation. The total thickness of the Nogaytinskaya Formation is 5-10 m. Typically clayey siltstones are in the upper portion, with beds of mollusca and selachians of the *Palaeoanacorax obliquus* Zone toward the middle-

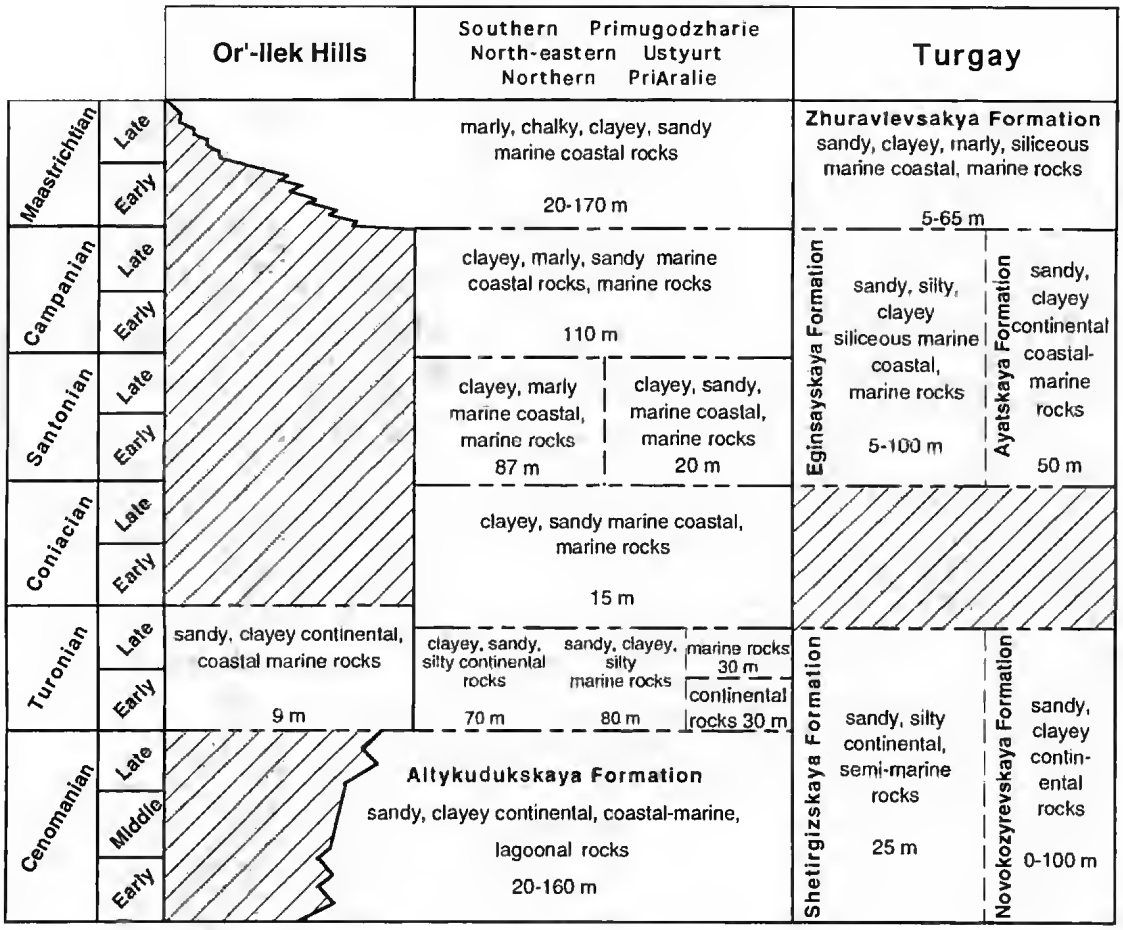

FIG. 4. — Correlation of the Or'-Ilek Hills, southern Primugodzharie, and Turgay.

to lower portion of the section. Conglomerates and sandstones are in the bottom of the section (Zhelezko & Segedin 1972).

CENOMANIAN-TURONIAN (Figs 3-5)

The Cenomanian-Turonian rocks are widespread in the Turgay trough and represented by the Shetirgizskaya Formation (continental to semi-marine) and Novokozyrevskaya Formation (continental). Surface outcrops are only found in erosional and karst depressions.

Composition of the Shetirgirzkaya Formation varies with the area. In the northern part of the Turgay trough, the Shetirgirzkaya Formation is about 10 m thick, composed of green-green monmorillonite-beidellite sandy silty clay to kaolinite clays with lignite, coal and pyrite. This section lies unconformably on Carboniferous limestones, with Santonian marine deposits lying on top of the section (Papulov *et al.* 1990).

In the southern part on the Kazakh Republic, the deposits are thicker (up to 60 m) and range from coarse grained sandstones to silty claystones, with some plant debris. The lower portion of the Shetirgizkaya Formation contains spores/pollen of early Cenomanian age, while the upper portion corresponds to late Cenomanian-early Turonian. Flora of Cenomanian-Turonian age is also found of the Ayatskian regional flora (Shilin 1986). Marine deposits of the Santonian age lie on top, while Albian grey clays are at the base of the section.

The Novokozyrevskaya Formation lies on weathered Paleozoic rocks throughout the region. Overlying disconformably varies from Santonian, Campanian, Maastrichtian or Paleogene, depending on the location. A 43 m section is found in the Novokozyrevsky quarry, near the Tobol River near the town of Oktyabrsky. The bottom of the section contains kaolinite-hydromica clays with clasts of Paleozoic rocks. A 15 m layer of bauxite, which is commercially mined, is present up in the section. The top of the section is approximately 15 m of kaolinite-gibbsite dark clay with lignite and coaly plant deposit, with the uppermost containing bauxite with plant remains.

The Novokozyrevskaya Formation throughout this region ranges in thickness from 0-100 m.. It can be characterized by three parts including a lower coarse grained sandstone, a middle bauxite bearing layers, and an upper kaolinite clay with plant remains. The lower part usually contains spores/pollen association of early Cenomanian age, with the middle and upper layers containing late Cenomanian-early Turonian age (Papulov *et al.* 1990).

There are other Cenomanian-Turonian deposits in the western side of the Turgay trough, deposited in a lacustrine/continental environment. It outcrops in karst depression and other erosional regions. Near the Ayat River, an outcrop of approximately 16 m is found. The base of the section has sandstones with Paleozoic weathering debris. Kaolinite clays with lignite overly grade into quartz rich sands toward the top of the section. Santonian oolitic bearing sands are found lying conformably on the top of the section. This deposit contains spores/pollen of late Cenomanian-early Turonian age, with a flora assemblage of Turonian age called the Ayatskian-Kazakhstanian flora (Shilin 1986).

In the north-eastern corner of the Turgay region, the Upper Cretaceous sedimentary sequence of Turgay, is replaced by West Siberian sequences. The semi-marine deposits of Shetirgizskaya Formation is gradually replaced by the semi-marine West Siberian Uvatskaya Formation, which contains the *Trochammina wetteri-Trochammina subbotinae* Zone of late Cenomanian. The radiolarian zonation also correlates a late Cenomanian age (*Cenodiscus cenomanicus-Stichocapsa ferosia uvatica* Zone).

TURONIAN (Figs 3-6)

Continental, marine, and coastal-marine deposits of Turonian age are widespread in southern Primugodzharie, northern PriAralie, and Turgay Trough in subsection. The thickness of Turonian deposits ranges from several meters in the north to 80 m in the south in the southern Primugodzharie, and increases to 300 m in the PriAralie region.

In the Aktyubinskian Priuralie, deposits of Turonian age are found on Cenomanian sandstones along the Ilek River. Marine clay rich quartz sandstones and clays (up to 12 m) are found with *Inoceramus* and ammonites of the late Turonian *Inoceramus labiatus* Zone and foramini-

		Foraminifera			Radiolaria	Belemnites	Selachians	Mollusca
Maastrichtian	Late	Hanzawaia ekblomi		Spiroplectammina kasanzevi		Neobelemnella kazimiroviensis	Squalicorax pristodontus	Oxyotoma danica
		Brotzenella praeacuta						
	Early	Gaudryina rugosa spinulosa			Orbiculiforma renillaeformis	Belemnella sulm. sumensis		Oxyotoma uralica
						Belemnella lanceolata		
						Belemnella lichareví		
Campanian	Late	Bolivina kalinini - Brotzenella taylorensis			Amphipyndax stocki	Belemnella ex gr. langei	Squalicorax ex gr. pristodontus	Inoceramus balticus
		Spiroplectammina optata				Belemnella mucronata mucronata		
	Early	Spiroplectammina senonana pocurica			Prunobrachium crassum	Belemnellocamax mammillatus	Squalicorax plicatus	
						Belemnitella mucronata alpha		
						Actinocamax laevigatus	Squalicorax lindstromi	
						Belemnitella praecursor mucronaliformis		
Santonian	Late	Ammobaculites dignus Pseudoclavulina hastata admota				Belemnitella praecursor praecursor	Squalicorax kaupi	Oxyotoma tenuicostata
	Early					Goniocamax lundgreni vilicus	Squalicorax papulovi	Inoceramus cardissoides
							Squalicorax santonicus	
Coniacian	Late		Haplophragmium chapmani Ammoscalaria antis Reussella kelleri			Goniocamax lundgreni lundgreni	Squalicorax falcatus	Inoceramus schloenbachi
	Early							
Turonian	Late					Goniocamax intermedius	Squalicorax sagiscus	Inoceramus labiatus
							Palaeonacorax intermediumus	
	Early							
Cenomanian	Late	Ligulogavelinella globosa		Trochammina welteri Trochammina subbotinae	Stichocaspa ferosia utavica			
				Rotalipora cushmani				
	Middle	Gavelinella cenomanica	Gavelinella baltica	Thalmanninella deeckei			Palaeonacorax obliquus	Kamaroites grossouvrei
	Early		Hoeglundina postdorsoplana	Thalmanninella appenninica			Palaeonacorax volgensis	Oxytoma pectinata

FIG. 5. — Correlation of foraminiferans, radiolarians, belemnites, selachians, and mollusca in the southern Urals region (adapted from Naidin *et al.* 1984a, b; Naidin & Kopaevich 1977; Azbei & Grigyalis 1991).

fers of the late Turonian *Gavelinella moniliformis* Zone. Santonian rocks are found conformably on top of this section.

In the Kazakh Republic, near Novofedorovsky, a 13 m section lies on Cenomanian sandstones. The section contains a phosphoritic horizon of concretions in quartz-glauconite sandstone. Dark grey to green grey clayey marls are found in the rest of the section. The section is overlain by Santonian phosphoritic layer.

In the Or'-Ilek Hills area, in the Kirgeldinsky graben on the Ural River, the Turonian is represented by micaceous quartz rich sandstones and siltstones. *Inoceramus lamarcki* park can be found in this region.

The Turonian deposits of the southern Primugodzharie outcrop near the flanks of the Shoshkakolian anticlinorium. In the northern portion of this area the deposits are continental, but become more influenced by marine sedimentation in the south of the Shoshkakolian Range area. On the Ustyurt plateau and in the north-western part of the PriAralie (Kulandy Peninsula of the Aral Lake), the Turonian deposits are marine. In the south-eastern Turgay area, the Turonian rocks range from continental (earliest sedimentation) to coastal-marine (latest). Continental deposits of kaolinite clays, sandstones, and siltstones are called the Zhirkindekskaya Formation in the southern Primugod-

		Russian Platform	Western Kazakhstan	Crimea, Caucasus, Carpathians
Maastrichtian	Late	*Hanzawaia ekblomi*	*Pseudotextularia varians*	*Abathomphalus mayaroensis*
			Brotzenella praeculata	
	Early	*Brotzenella complanata*	*Bolivinoides draco draco*	*Globotruncana stuarti*
			Brotzenella complanata	
		Angulogavelinella gracilis		
Campanian	Late	*Globorotalites embdyensis*	*Brotzenella taylorensis* *Bolivina kallmini* *Cibicidoides voltzianus*	*Globotruncanita morozovae*
		Brotzenella montereiensis		
	Early	*Cibicidoides termirensis*	*Cibicidoides termirensis* *Cibicidoides aktulagayensis*	
			Bolivnoides decoratus decoratus	
		Gavelinella clementiana clementiana		
Santonian	Late	*Gavelinella stelligera*	*Bolivinoides strigillatus*	*Globotruncana fornicata*
			Osangularia whitei whitei	
	Early	*Gavelinella infrasantonica*	*Stensioeina granulata perfecta*	*Globotruncana concavata*
Coniacian	Late	*Gavelinella costulata*	*Stensioeina exculpta granulata*	*Globotruncana primitiva*
			Stensioeina granulata granulata	
	Early	*Gavelinella kelleri*		*Globotruncana angusticarinata*
Turonian	Late	*Gavelinella moniliformis*	*Gavelinella praeinfrasantonica*	*Globotruncana lapparenti*
		Gavelinella ammonoides	*Gavelinella moniliformis*	
	Early	*Gavelinella nana*	*Globorotalites hangensis*	*Helvetoglobotruncata helvetica*
			Hedbergella holtzi	

FIG. 6. — Correlation of foraminifera zones from the Russian Platform, western Kazakhstan and Crimea, Caucasus, and Carpathians (western part of the west European Paleobiogeographic provinces).

zharie, northern PriAralie, and south-western Turgay.

Marine deposits of Turonian-Coniacian age composed of greenish monmorillonite with admixture of kaolinite, with interlayers of glauconite quartz rich siltstones, clayey siltstones, and fine grained sandstones are found in Northern PriAralie. The total thickness of these deposits are approximately 100 m. These deposits contain macrofossils of the late Turonian *Inoceramus labiatus* Zone and Coniacian *Inoceramus schloenbachi* Zone (Yanshin 1953).

In the eastern PriCaspian region, late Turonian deposits are light grey - grey sandy limestones, carbonate sands, with a phosphoritic horizon in the base. The total thickness ranges from 2-25 m. These marine deposits contain macrofossils of the late Turonian *Inoceramus labiatus* Zone, *Squalicorax sagisicus* Zone and the foraminiferal *Gavelinella moniliformis* Zones. Continental deposits contain spore/pollen in the SPA IV.3 Zone.

The Ayatskaya Formation in Turgay, was formerly considered Turonian deposits, but is not considered Turonian in this study. In the north-eastern region of the Turgay region near the boundary of the West Siberian platform, the Turgay faunas are replaced by West Siberian faunas. The foraminifera and radiolaria indicate Turonian age in the West Siberian Uvatskaya and Kuznetsovskaya Formations (Amon 1988, 1990).

CONIACIAN (Figs 3-6)

Coniacian deposits are absent from the majority of the region, but are found in the extreme west, south, and east. These deposits may have been eroded during a very dynamic transgression during the Santonian-Campanian.

In the Western Primugodzharie region, marine rocks of Coniacian age are present. They are chalky marls, marls and clays with a thickness of approximately 5 m. In the south-western to southern Primugodzharie, 15 to 20 m of marine blue-grey sandy limestones with phosphoritic concretions and sandy carbonate claystones are Coniacian. This deposit contains the molluscan *Inoceramus schloenbachi* Zone and the foraminiferal *Gavelinella kelleri* Zone (early Coniacian) and late Coniacian *Gavelinella costulata* and *Stensioeina granulata granulata* Zone.

In western Primugodzharie and Aktyubinskian Priuralie, the upper Coniacian deposits are represented by the lower portion of the Kubleyskie beds, which is found in the basal section of the Koldenen-Temirskaya Formation. It is light green, fine grained sandstones and siltstones with a phosphoritic unit (Zhelezko & Segedin 1972; Zhelezko 1987, 1988). Upper Coniacian belemnites of the *Goniocamax lundgreni lundgreni* Zone and selachians of the *Squalicorax falcatus* Zone are found in this horizon. These are transgressive deposits found on Cenomanian sandstones of the Altykudukskaya Formation; on marls of Turonian age; and/or on deposits of the Zhirkindekskaya Formation. In the Turgay Trough, Coniacian intervals are not found. Sedimentological evidence shows that they were probably eroded. It has been suggested that portions of the Eginsayskaya Formation, in the northern part of Turgay, is Coniacian. This correlation is only possible because the Eginsayskaya Formation in West Siberia contains Coniacian foraminifers of the *Haplophragmium chapmani-Ammoscalaria antis-Reusella kelleri* Zone and Coniacian radiolarians of the *Ommatodiscus mobilis* Zone (Amon 1988, 1990).

SANTONIAN-CAMPANIAN (Figs 3-6)

Marine deposits of Santonian-Campanian age are found in the western Primugodzharie and Aktyubinskian Priuralie. Upper Coniacian-lower Campanian deposits of the Koldenen-Temirskaya Formation includes two lithologic units. The lower unit is sandy-phosphoritic Kubleskie Beds and is 9 m thick. The upper unit is a phosphoritic siltstone, 17 m thick, called the Zhurunskie Beds. Lower-upper Campanian Zharykskaya Formation and upper Campanian Kursayskaya Formation are also found in these regions.

Outcrops of the Koldenen-Temirskaya and Zharykskaya Formation on the Temir, Koldenen-Temir, and Kubley Rivers have provided a continuous section. This sequence contains late Coniacian, Santonian and early Campanian deposits.

Light green, fine grained sandstones and siltstones with a phosphoritic horizon make up the Coniacian interval. Lower Santonian intervals,

ranging from siltstones to fine grained sandstones, contain two phosphoritic horizons. Early Santonian belemnites of the *Goniocamax lundgreni uilicus* Zone and selachians of *Squalicorax santonicus* Zone and *Squalicorax paulovi* Zone are helpful to define this layer. Foraminifers of the *Stensioeina exculpta exculpta* Zone and *Stensioeina granulata perfecta* Zone indicate an early Santonian age. The late Santonian interval contains belemnites of the *Belemnitella praecursor praecursor* Zone, bivalves of the *Oxytoma tenuicostata* Zone, selachians of the *Squalicorax kaupi* Zone, and foraminifers of the *Gavelinella stelligera* Zone. Early Campanian contains belemnites of *Actinocamaax laevigatus-Belemnitella praecursor mucronatiformis* Zone, selachians of *Squalicorax lindstromi* Zone, foraminifers of *Gavelinella clementiana clementiana* Zone and *Bolivinoides decoratus decoratus* Zone.

Zharykskaya Formation in western Primugodzharie and Aktyubinskaian Priuralie, was deposited transgressively over the Koldenen-Temirskaya Formation. Rhythmically alternating layers (5-7 m thick) of silty, marly, dark grey to green-grey clays, and glauconite light grey, yellow grey siltstones with phosphoritic concretions, reach a thickness of 40 m in the Zharyskaya Formation (Zhelezko & Segedin 1972; Zhekezko 1988; Naidin *et al.* 1991). Rocks in the lower portion contain early Campanian belemnites of the *Belemnellocamax mammilatus-Belemnitella mucronata alpha* Zone; selachians of the *Squalicorax plicatus* Zone and foraminifers of the *Cibicidoides temirensis* Zone. The upper portion of the formation contains late Campanian belemnites of the *Belemnitella mucronata mucronata* Zone, foraminifers of *Brotzenella monterelensis* Zone and *Cibicidoides voltzianus* Zone.

The late Campanian Kursayskaya Formation in the western Primugodzharie and Aktyubinskian Priuralie transgressively lies on the Zharykskaya Formation. The Kursayskaya Formation is composed of calcareous light-yellow-grey siltstones, silty marls with isolated phosphoritic concretions, as well as phosphoritic horizon toward the base of the formation, with a thickness of 15 m. Late Campanian belemnites of the *Belemnitella* ex gr. *langei* Zone, mollusca of the *Inoceramus balticus* Zone, selachians of the *Squalicorax* ex gr. *pristodontus* Zone, foraminifers of the *Bolivina kalinini* Zone and *Brotzenella taylorensis* Zone are found in this area (Zhelezko & Segedin 1972; Zhelezko 1988; Naidin *et al.* 1991).

In the eastern margin of the PriCaspian Zone, Santonian marine deposits, mixed with Campanian deposits, are widespread. The Santonian deposits can be divided into lower and upper units. The lower Santonian sediments are 10-50 m of light grey, green-grey, blue grey sandy limestones, with rare phosphoritic concretions. Interlayers of calcareous sands and chalk-like, clayey limestones are also present. There are belemnites of the *Goniocamax lundgreni uilicus* Zone (early Santonian), selachians of *Squalicorax santonicus* Zone (early Santonian), selachians of *Squalicorax papulovi* Zone (early-middle Santonian); foraminifers of *Stensioeina exculpta exculpta* Zone (early Santonian or late Coniacian-Early Santonian). The upper Santonian sediments range in thickness from 5-35 m and are light grey, green-grey, blue-grey sandy clays and limestones, with rare phosphatic and pyritic concretions. There are belemnites of *Belemnitella praecursor praecursor* Zone (late Santonian); mollusca of the *Oxytoma tenuicostata* Zone (late Santonian); selachians of the Late Santonian *Squalicorax kaupi* Zone; foraminifers of *Gavelinella stelligera* Zone (late Santonian or late Santonian-early Campanian).

The Campanian deposits of the Eastern PriCaspian Zone are divided into lower and upper sedimentary units. Lower Campanian sediments (5-30 m) are light grey, chalk-like limestones, marls, calcareous clays with belemnites of *Actinocamax laevigtus-Belemnitella praecursor mucronatiformis* Zone (early Campanian), *Belemnellocamax mammilatus-Belemnitella mucronata alpha* Zone (early Campanian); selachians of *Squalicorax lindstromi* Zone (early Campanian), *Squalicorax plicatus* Zone (early Campanian); and foraminifers of *Gavelinella clementiana clementiana* Zone (early Campanian), *Bolivinoides decoratus decoratus* Zone (early Campanian), *Cibicidoides temirensis* Zone (early Campanian). Upper Campanian sediments are light green to grey, sandy marls, clayey chalk and range in thickness 5-30 m. There are belemnites of *Belemnitella mucronata mucronata* Zone (late

Campanian), *Belemnitella* ex gr. *langei* Zone (late Campanian), foraminifers of *Brotzenella monterelensis* Zone (late Campanian), *Cibici-doides voltzianus* Zone (late Campanian), *Bolivina kalinini* Zone (late Campanian), and *Brotzenella taylorensis* Zone (late Campanian) (Naidin *et al.* 1991)

Santonian-Campanian marine rocks in the northern portion of PriAralie and southern Turgay are transgressively laid on continental Turonian-Coniacian deposits (Papulov & Naidin 1979). The lower units have a thin layer (1-2 m) of conglomerate which contains sands, phosphoritic concretions, pebbles of argillites, mollusca, shark teeth, silicified wood, cemented with calcareous clay. Santonian deposits include marine sands with gravel and phosphoritic concretions. Mollusca of the late Santonian age, *Oxytoma tenuicostata* Zone; selachians of *Squaliconax kaupi* Zone. Campanian deposits are represented by the calcareous clays and marls with belemnites of *Belemnitella mucronata* Schloth., *s.l.*; foraminifers of Early Campanian *Cibicidoides temirensis* Zone which resembles the Early Campanian Zones of the Mangyshlak and PriCaspian depressions.

In the Turgay Trough, the Santonian-Campanian sediments are represented by the Eginsayskaya and Ayatkaya Formations. Thickness and position of these deposits are dependant on the relief on which they were lain and the dynamics of coastal marine deposition. The Eginsayskaya Formation ranges, in thickness from 5-150 m, is widespread reflecting coastal, shoreline and lagoonal deposits. The Ayatskaya Formation is found only in isolated areas (Ayat river near Taranovskoe, Sokolovsky and Sarbaysky quarries near Rudnyi city in Kustanay area) and reflects lagoonal sediments that are gradually replaced by the marine rocks of the Eginsayskaya Formation.

The Eginsayskaya Formation is best exposed in the Kachar quarry (Fig. 6). The Novokozyrevskaya Formation overlies continental Jurassic deposits. The formation is Ceno-manian in age, determined by spores and pollen. The sedimentary rocks include interlayering of grey-pink clays, multicolored silty clays, silty bauxite, black and brown lignite, and viscous grey clays. The total thickness is 11.3 m.

An unnamed 15.8 m group of rocks overlies the Novokozyrevskaya Formation. It is analogous to the Kuznetsovskaya Formation of West Siberia. Spores and pollen give this group an age of Turonian. The sedimentary rocks include laminated, yellow-grey, quartz rich medium grained sandstones and yellow-grey silty clays. This group is terminated by a stratigraphic unconformity.

The Eginsayskaya Formation is composed of both Santonian and Campanian rocks. The Santonian Eginsayskaya Formation is confirmed by several fossil groups. A 5.3 m thick horizon of dark-grey platy clays with interlayering of glauconite quartzeous siltstones and concretions of siderite uses pollen and spores. A 3.3 m horizon of green-grey siltstones and sandstones has evidence from cephalopods (*Baculites*), bivalves (*Trigonia*), selachian, spores and pollen. Spores and pollen are used in a 3.1 m thick horizon of dark-grey, black solid silty clays. A 4.1 m thick horizon of green-grey clayey quartz-glauconite sandstones and siltstones, with interlayers of sandy dark-grey clays, are in the *Ammobaculites dignus-Pseudoclavulina hastata admota* foraminifer Zone and are found along with selachian, spores and pollen.

In the Maastrichtian Zhuravlevskaya Formation cephalopods (belemnites) and foraminifera (*Gaudryina rugosa spinulosa* assemblage) are present. Interlayering of silicified calcareous siltstones and opokas (siliceous mudstones) are found throughout its thickness of 6.0 m. A sandy marl with a thickness of 5.0 m contain cephalopods (belemnites) and foraminifera of *Spiroplectammina kasanzevi* assemblage. Marine Paleogene deposits lie conformably above the Zhuravlevskaya Formation.

The Ayatskaya Formation lies on 0.6-3 m of conglomerates and sandstones. Deposits up to 7 m are dark-grey, green-grey glauconite quartz rich siltstones with spores and pollen, indicating an early Santonian age. Mollusca from the *Inoceramus cardissoides* Zone (early Santonian) are found in coarse glauconite sandstones with beidellite-montmorillonite-halloysite clays with sideritic and iron-ore concretions (1.5-5 m). This is followed by 2 m of green grey to yellow siltstones and fine grained poorly cemented sandstones and 1.5 m of dark beidellite-montmorillonite-halloysite clays with gypsum,

siderite and iron ore concretions. A red to yellow brown, yellow green oolitic iron ores in sands and clays is approximately 1-2 m just before a stratigraphic unconformity. Campanian sediments of fine to medium grained diagonally bedded sandstones with mollusca make up 2 m. It contains late Campanian fossils of *Pycnodonta* sp., *P.* cf. *hippopodium*, *Acutostrea* cf. *acutirositris*, *Inoceramus* sp., *I.* cf. *balticus* and foraminifers of *Spiroplec-tammina optata* Zone.

Santonian interval contains the spores and pollen of SPA IV; foraminifers of *Ammobaculites dignus-Pseudoclavulina hastata admota* Zone, as well as the bivalves of Turgayan *Inoceramus cardissoides* Zone (early Santonian) and selachians of *Squalicorax santonicus* Zone and *Squalicorax papulovi* Zone (early Santonian), selachians of *Squalicorax kaupi* Zone. Campanian interval contains the spores and pollen association SPA IV.5; selachians of *Squalicorax lindstromi* Zone (early Campanian); *Squalicorax plicatus* Zone (early Campanian); *Squalicorax* ex gr. *pristodontus* Zone (late Campanian); radiolarians of *Prunobrachium crassum* Zone (early Campanian), *Amphipyndax stocki* Zone (late Campanian); foraminifers of *Spiroplectammina senonana pocurica* Zone (early Campanian); *Spiroplectammina optata* Zone (late Campanian), *Bolivina kalinini-Brotzenella taylorensis* Zone (late Campanian) (Amon 1987).

MAASTRICHTIAN (Figs 3-6)

The western portion of the Primugodzharie and Aktyubinskian Priuralie marine deposits of Maastrichtian age are represented by a calcareous clay marl of the Zharskaya Formation. A total thickness of 15 m of light grey siltstones and marls contain phosphoritic concretions throughout the deposit. Marls in the lower part of the section contain belemnites of *Belemnella lanceolata* Zone, *Belemnella sumensis sumensis* Zone, *Belemnella sumensis pristodontus* Zone; it contains also foraminifers of *Angulogavelinella gracilis* Zone, *Brotzenella complanata* Zone and *Bolivinoides draco draco* Zone. Marls of the upper part of the formation contain belemnites of *Neobelemnella kazimiroviensis* Zone; mollusca of *Oxytoma danica* Zone and *Pseudotextularia elegans* Zone.

In the eastern margin of the eastern PriCaspian Zone, Maastrichitian deposits are widespread. The early Maastrichtian sediments are transgressively occurring on Campanian rocks and composed of chalk, chalky limestone with belemnites of *Belemnella lanceolata* Zone, *Belemnella sumensis sumensis* Zone; foraminifers of *Angulo-*

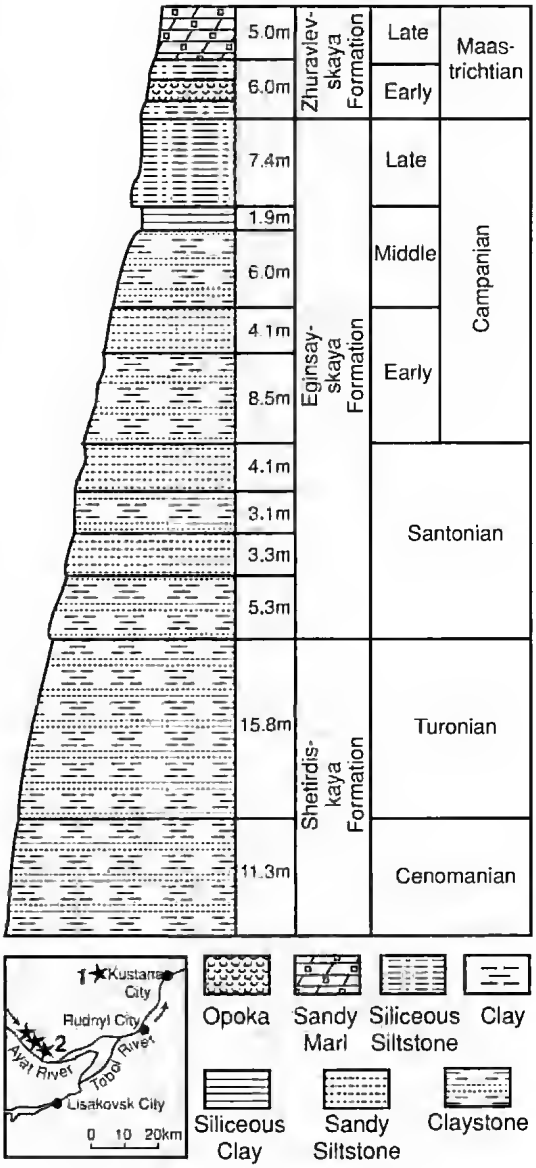

FIG. 7. — Columnar section of the Kachar quarry reference section.

gavelinella gracilis Zone; *Brotzenella complanata* Zone and *Bolivinoides draco draco* Zone; thickness is 30-60 m. Upper Maastrichtian sediments, ranging from 12-80 m thick, are represented by the same rocks with belemnites of *Neobelemnella kazimiroviensis* Zone; mollusca of *Oxytoma danica* Zone; foraminifers of *Brotzenella praeacuta* Zone, *Pseudotextularia elegans* Zone (Naidin *et al.* 1991).

In northern PriAralie and south-western Turgay, Maastrichtian deposits are transgressively deposited on Santonian-Campanian rocks or Paleozoic rocks. They are represented by marls, chalks, clayey siltsrones, calcareous siltstones, sands and sandstones, cemented by calcareous clay. Mollusca, belemnites and brachiopods can be found within the 30-50 m thick formation. Early Maastrichtian deposits contain belemnites of *Belemnella lanceolata* and foraminifers of *Gaudryina rugosa spinulosa* Zone. The foraminifera zone can be correlated to deposits in the Magyshlak and PriCaspian depression. The Late Maastrichtian deposits contain belemnites of the *Neobelemnella kazimiroviensis* Zone and foraminifers of *Spiroplectammina kasanzevi* Zone, which can also be correlated to the Magyshlak and PriCaspian depression.

In the Turgay area, the Maastrichtian deposits include calcareous sandstones and silty clays, calcareous siltstones, marl, quartz-glauconite sands and sandstones of the Zhuravlevskaya Formation. This formation ranges in thickness from 5-85 m and is rarely found in outcrops except in the river valleys of the western portion of the Turgay trough. The Kachar quarry (Fig. 7) and Ayat River sections are the best reference sections. Thick Paleogene deposits cover most of the Zhuravlevskaya Formation.

The Zhuravlevskskaya Formation contains early Maastrichtian spores and pollen of the SPA IV.6 and rare belemnites of the early Maastrichtian *Belemnella sumensis* Zone. Mollusca of the *Oxytoma uralica* Zone is found in the north-eastern portion of the Turgay trough. Radiolarians of the *Orbiculiforma renillaeformis* Zone and foraminifers of the *Gaudryina rugosa* Zone reflect early Maastrichtian.

Late Maastrichtian intervals contain belemnites of *Neobelemnella kazimiroviensis* Zone, foraminifers of *Brotzenella praeacuta* Zone and *Hanzawaia ekblomi* Zone (late Maastrichtian) (Amon 1987).

SUMMARY

During the Cretaceous, microfossils are important to correlate on a global and interregional scale, especially in the Peri-Tethys area (Amon & De Wever 1994). The correlation proposed by Koch (1977) is mainly valid for western and north-western Europe. The zonal scale based on ammonite and belemnite zonation is only valid for European Russia, Ukraine, Byelorussia, Moldavia, and southern adjacent countries (Zhamoida 1989, 1994). The zonation shown in figures 5 and 6 can be used in the southern Urals to help correlate to the East European platform during the Cretaceous. The regional stratigraphy and correlation are summarized in figures 3 and 4.

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APPENDIX

CONTENT OF BIOSTRATIGRAPHIC ZONES

BELEMNITES

- *Neobelemnella kazimiroviensis* Zone: *Neobelemnella kazimiroviensis* (Skolozdr.), *Belemnella* sp., *B. sumensis sumensis* Jel., *B. sumensis praearkhangelskii* Naid.
- *Belemnella sumensis sumensis* Zone: *Belemnella* sp., *B.* ex gr. *sumensis* Jel., *B. sumensis sumensis* Jel., *B.* ex gr. *lanceolata* (Schloth.).
- *Belemnella lanceolata* Zone: *Belemnella* sp, *B.* ex.gr. *lanceolata* (Schloth.), *B. lanceolata* (Schloth.), *B.* ex gr. *sumensis* Jel.
- *Belemnella licharevi* Zone: *Belemnella* sp., *B. licharevi* Jel.
- *Belemnitella* ex gr. *langei* Zone: *Belemnitella* ap., *B. langei langei* Schatsk., *B. langei minor* Jel., *B. langei najdini* Kon.
- *Belemnitella mucronata mucronata* Zone: *Belemnitella* sp., *B* ex gr. *mucronata* (Schloth.), *B. mucronata mucronata* (Schloth.) Arkh.
- *Belemnellocamax mammilatus-Belemnitella mucronata alpha* Zone: *Actinocamax* sp., *Belemnellocamax mammilatus* (Nilss.), *Paractinocamax* ex gr. *grossouvrei* (Janet.), *Belemnitella* sp., *B. mucronata mucronata* (Schloth.), *B. mucronata alpha* Schatsk.
- *Actinocamax laevigatus-Belemnitella praecursor mucronatiformis* Zone: *Actinocamax* sp., *A. laelligatus* Arkh., *Paractinocamax* ex gr. *grossouvrei* (Janet.), *Belemnitella* sp., *B. praecursor media* Jel., *B. praecursor mucronatiformis* Jel.
- *Belemnitella praecursor praepraecursor* Zone: *Actinocamax* sp., *A.* ex gr. *verus* Mill., *A. verus fragilis* Arkh., *Belemnitella* sp, *B.* ex gr. *praecursor* Stoll., *B. praecursor praepraecursor* Naid., *B. praecursor media* Jel.
- *Goniocamax lundgreni uilicus* Zone: *Actinocamax* sp., *A.* ex gr. *verus* Mill., *A. verus fragilis* Arkh., *Goniocamax* ap., *G. lundgreni uilicus* (Kolt.).
- *Goniocamax lundgreni lundgreni* Zone: *Goniocamax* sp., *G. intermedius* (Arkh.), *G.* ex gr. *lundgreni* (Stoll.), *G. lundgreni lundgreni* (Stoll.).
- *Goniocamax intermedius* Zone: *Goniocamax* sp., *G. intermedius* (Arkh.).

MOLLUSCA

- *Oxytoma danica* Zone: *Teniupteria argentea* (Conrad), *Oxytomadanica* (Ravn).
- *Oxytoma uralica* Zone: *Chlamys pulchellus* (Nilss.), *Pycnodontevesiculare* (Lam.), *Oxytoma uralica* Glazun.
- *Inoceramus balticus* Zone: *Inoceramus balticus* Boehm., *Pycnodontehippopodium* (Nilss.), *Acutostrea* aff. *acutirostris* (Nilss.), *Chlamys* spp., *Dianchora labiata* (Wahl.)
- *Inoceramus azerbaidjanensis* Zone: *Inoceramus* sp., *In. azerbaidjanensis* Aliev.
- *Oxytoma tenuicostata* Zone: *Sphenoceramus angustus* (Beyenburg), *S. papulovi* Atabekjan, *S.* cf. *lingua* (Goldf.), *Inoceramus cycloides* Wegner, *Oxytoma tenuicostata* (Roem.), *Pycnodonte vesiculare* (Lam.), *Gryphaeostrea lateralis* (Nilss.), *Lopha semiplana* (Sow.), *Acutostrea curvirotris* (Nilss.).

- *Inoceramus cardissoides* Zone: *Inoceramus cardissoides* Gold-F., *I. pachti* Arkh., *Korobkovitrigonia amudariensis* (Arkh.), *K. tobolica* Pojark., *Chlamys faujasi* (Deft.).
- *Inoceramus schloenbachi* Zone: *Inoceramus* sp., *I.* ex gr. *kleini* Muell., *I. shloenbachi* Bochm.
- *Inoceramus labiatus* Zone: *Inoceramus cuvieri* Sow., *I. labiatus* Schloth., *I. lamarcki* Park., *I. websteri* Mant., *Placenti cerasplacenta* Dckay, *P. arkhangelskii* Iljin, *Collignoniceras woolgari* Mant.
- *Kamaroites grossouvrei* Zone: *Kamaroites* sp., *K.* aff. *subtilis* (Iljin), *K. grossouvrei* (Sem.), *K. mediasiaticum* (Luppov), *Schloenbachia varians* (Sow.), *S. varians* cf. *febramata* (Sow.), *S. subvarians* Spath., *S. ventricosa* Stieler, *Sciponoceras baculoides* (Mant.), *Mantelliceras mantelli* (Sow.).
- *Oxytoma pectinata* Zone: *Inoceramus crippsi* Mant., *I. orbicularis* Muenst., *I. pictus* Sow., *I. orbicularis* Muenst., *Oxytoma pectinata* (Sow.), *Entoliuri orbiculare* (Sow.), *E. noetlingi* (Sob.), *Acutostrea delettrei* (Coq.), *Amphiodonte conicum* (Sow.).

SELACHIANS

- *Squalicorax pristodontus* Zone: *Squalicorax pristodontus* (Ag.), *Pseudocorax affinis* (Ag.), *Cretolamna borealis* Prim.
- *Squalicorax* ex gr. *pristodontus* Zone: *Squalicorax* ex gr. *pristodontus* (Ag.), *Pseudoisurus* ex gr. *laevis* Leriche.
- *Squalicorax plicatus* Zone: *Squalicorax plicatus* (Priem.), *Paraanacorax* ex gr. *obruchevi* Glueck., *Scapanorhynchus* ex gr. *raphiodon* (Ag.), *Rhaphiodiscus texanus* (Roem.).
- *Squalicorax lindstromi* Zone: *Acrolamna acuminata dilatata* Zhel., *Protolamna arcuata* (Woodw.), *Squalicorax lindstromi* (David), *Paraanacorax obruchevi* Glueck., *Eostriatolamia lerichei* Glueck. *et* Zhel.
- *Squalicorax kaupi* Zone: *Acrolamna acuminata* (Ag.), *Protolamna adunca subcrecta* Zhell., *Squalicorax kaupi* (Ag.), *Eostriatolemia segedini* Glueck. *et* Zhel., *E. venusta* (Leriche), *Scapanorhynchus raphiodon* (Ag.).
- *Squalicorax papulovi* Zone: *Squalicorax papulovi* Zhel., *Eostriatolamia aktobensis* Zhel., *Scapanorhynchus temirensis* Zhel., *Ptichocorax dolloi* (Leriche), *Ptychodus deccurrens* Ag.
- *Squalicorax santonicus* Zone: *Squalicorax santonicus* Glueck. *et* Zhel., *Ptychocorax dolloi* (Leriche), *Microanacorax praeyangaensis* Glueck., *Eostriatolamia* ex gr. *venusta* (Leriche), *Cretoxyrhina mantelli* (Ag.), *Pseudocorax laevis* Leriche.
- *Squalicorax falcatus* Zone: *Squalicorax falcatus* (Ag.), *Microanacorax* ex gr. *praeyangaensis* Glueck., *Eostriatolamia* ex gr. *venusta* (Leriche), *Ptychodus* ex gr. *venusta* Dixon.
- *Squalicorax sagisicus* Zone: *Cretilamna appendiculata* (Ag.), *Squalicorax sagisicus* Glueck., *Acrolamna* ex gr. *crassicornis* Zhel.
- *Palaeoanacorax intermedius* Zone: *Paleoanacorax intermedius* Glueck., *Eostriatolamia* ex gr. *angustidens* (Ag.), *Scapanorhynchus* ex gr. *raphiodon* (Ag.).
- *Palaeoanacorax obliquus* Zone: *Paleoanacorax obliquus* (Reuss.), *Pseudoisurus semiplicatus* (Ag.), *Eostriatolamia* ex gr. *subulata* (Ag.), *Cretoxyrhina basalis* (Giebel.).
- *Palaeoanacorax volgensis* Zone: *Paraisurus macrorhizus* (Pict. *et* Camp.), *Cretodus suloatus* (Gein.), *Cretoxyrhina denticulata* Glueck., *Palaeoanacorax volgensis* Glueck., *Hispidaspis gigas* (Woodw.).

FORAMINIFERA

Maastrichtian, Late 2

- *Pseudotextularia elegans* Zone: *Cibicidoides clipeatus* (Vass.), *Gavelinella danica* (Brotz.), *Hanzawaia ekblomi* (Brotz.), *Pseudotextularia elegans* Rzeh., *Pseudotextularia varians* Rzeh.

Maastrichtian, Late 1

- *Brotzenella praeacuta* Zone: *Anomalinoides pinguis* (Jenn.), *Brotzenella praeacuta* (Vass.), *Cibicides kurganicus* Neck., *Gavelinella midwayensis* (Plumm.), *Gavelinella pertusa* (Marss.), *Gavelinella welleri* (Plumm.), *Globigerinelloides subcarinatus* (Bronn.), *Gyroidinoides globosus* (Hag.), *Pseudouvigerina cristata* (Marss.), *Tappania seulmensis* (Cushm.).

Maastrichtian, Late, PriAralie

- *Spiroplectammina kasanzevi* Zone: *Anomalinbides justus* Podob., *Brotzenella pseudopapilosa* (Cars.), *Bulimina rosenkrantzi* Brotz., *Heterostomella foveolata* (Marss.), *Quinqueloculina fusiformis* Putrja, *Spiroplectammina kasanzevi* Dain.

Maastrichtian, Late 2, Turgay

- *Hanzawaia ekblomi* Zone: *Spiroplectinella sengibabensis* (Bala-khm.), *Gaudryina gigantica* Subb., *Angulogavelinella caucasica* (Subb.), *Hanzawaia ekblomi* (Brotz.), *Karreria fallax* Rzeh., *Bulimina eminenta* Ehrem., *Gueblerina robusta* De Klasz.

Maastrichtian, Late 1, Turgay

- *Brotzenella praeacuta* Zone: *Spiroplectammina kasanzevi* Dain, *Arenobulimina oblique* (Orb.), *A. presli* (Reuss), *Gaudryina rugosa rossica* Balakhm., *Gaudryinopsis subbotinae* (Kypr.), *Neoflabellina reticulata* (Reuss), *Valvulineria procera* Podobina, *V. imitata* Olss., *Gavelinella midwayensis* (Plumm.), *Cibicidoides bembix kazakhstanica* Neck., *Brotzenella praeacuta* (Vass.), *Anomalinoides pinguis pinguis* (Jenn.), *Nonionella kalinini* Volosh., *Reussella cimbrica* (Troels.), *R. bacillum* Ehrem., *Bolivina incrassata gigantea* Wicher, *Bolivinoides peterssoni* (Brotz.), *Rugoglobigerina rugosa* (Plumm.), *R. macrocephala* Broun., *Globotruncana havanensis* (Voorw), *Tritinella scatti* Bronn., *Heterohelix navarroensis* Loebl., *Pseudoguem-bellina kempensis* Esker, *P. palperba* Bronn. *et* Brown.

Maastrichtian, Early 3

- *Bolivinoides draco draco* Zone: *Bolivinoides draco draco* (Marss.),*Coleites crispus* Vass., *Gavelinella midwayensis* (Plumm.), *Rugoglobigerina rugosa* (Plumm.), *Spiroplectammina suturalis* Kal.

Maastrichtian, Early 2

- *Brotzenella complanata* Zone: *Angulogavelinella* ex gr. *caucasica* (Subb.), *Anomalinoides ukrainious* (Wolosch.), *Biglobigerinella biforaminata* (Hofk.), *Bolivina incrassata crassa* Vass., *Brotzenella complanata* (Reuss), *Gavelinella welleri* (Plumm.).

Maastrichtian, Early 1

- *Angulogavelinella gracilis* Zone: *Angulogavelinella gracilis stellaria* (Vass.), *Bolivina decurrens* (Ehr.), *Bolivinoides delicatulus* Cushm., *Bolivinoides peterssoni* Brotz., *Brotzenella taylorensis* (Cars.), *Cibicidoides bembix* (Marss.), *Gyroidinoides globosus* (Hag.), *Neflabellina praereticulata* Hilt., *Neflabellina reticulata* (Reuss), *Osangularia navarroana* (Cushm.).

Maastrichtian, Early, PriAralie

- *Gaudryina rugosa spinulosa* Zone: *Ataxophragmium rimosum* (Marss.), *Bulimina quadrata* Plumm., *Cibicidoides aktulagayensis* (Vass.), *C. spiropunctatus* (Gall. *et* Morr.), *C. bembix bembix* (Marss.), *Dorothia pupoides ovata* Podobina, *Gaudryina rugosa spinulosa* Neck., *Siphogaudryina stephensoni distincta* Podobina, *Spiroplectammina kelleri* Dain, *Spiroplectammina variabilis* Neck., *S. kelleri* Dairi, *Valvulineria imitata* Olss.

Maastrichtian, Early, Turgay

- *Gaudryina rugosa spinulosa* Zone: *Spiroplectammina brevis modesta* Kiss., *Spiroplectinella variaspera* (Kiss.), *S. baudouiniana* (Orb.), *Gaudryina rugosa spinulosa* Neck., *Siphogaudryina stephensoni* Cushm., *Quinqueloculina stolley* Brotz., *Lagena* spp., *Guttulina* spp., *Discorbis parvus* Ehrem., *Angulogavelinella gracilisstellaria* Vass., *A. praecaucasica* (Vass.), *Valvulineria lenticula* (Reuss), *Stensioeina pommerana* Brotz., *Gyroidinoides turgidus* (Hag.), *G. beresoviensis* (Balakhm.), *Osangularia navaroana* (Cushm.), *Gavelinella welleri* (Plumm.), *G. mira* Podob., *Cibicidoides voltzianus* (Orb.), *C. spiropunctatus* (Gall. *et* Morr.), *C. bembix* (Marss.), *Brotzenella complanata* (Reuss.), *B. menneri* (Kell.), *Heterolepa orcina* (Vass.), *Cibicides globigeriniformis* Neck., *C. gankinoensis* Neck., *C. kurganicus* Neck., *Nonionellina* spp., *Rheinholdella brotzeni* Olss., *Epistomina fax* Nauss, *Praebulimina carseyae* (Plumm.), *Bulimina* spp., *Bolivina incrassataincrassata* Reuss, *B. decurrens* (Ehrenb.), *Bolivinoides decoratusdracoformis* Vass., *B. draco miliaris* Hilt. *et* Koch., *B. senonicus* Dain, *Pullenia kazakhstanica* Dain, *P. americana* Cushm., *Quadrimorphina allomorphinoides* (Reuss).

Campanian, Late 4

- *Brotzenella taylorensis* Zone: *Bolivina incrassata incrassata* Reuss, *Bolivinoides giganteus* Hilt. *et* Koch, *Brotzenella taylorensis* (Cars.), *Globotruncana arca* (Cushm.), *G. morozovae* Vass., *Gyroidinoides turgidus* (Hag.), *Heterostomella praefoveolata* Mjatl., *Orbignyna inflata* (Reuss), *O. acheri* (Reuss), *Pseudouvigerina cristata* (Marss.), *Rugoglobigerina kelleri* (Subb.). *Stensioeina pommerana* Brotz.

Campanian, Late 3

- *Bolivina kalinini* Zone: *Bolivina kalinini* Vass., *Bolivinoides decoratus dracoformis* Vass., *B. miliaris* Hilt. *et* Koch, *Eponides frankei* Brotz., *Gavelinella cayeuxi mangyschlakensis* (Vass.), *Gemelliides orcinus* (Vass.), *Globotruncana majzoni* Sig. *et* Deb., *G. ventricosa* White, *Rugoglobigerina rugosa* (Plumm).

Campanian, Late 2

- *Cibicidoides voltzianus* Zone: *Cibicidoides voltzianus* (Orb.), *Gavelinella clementiana laevigata* (Marie), *Globorotalites* emdyensis Vass., *Globotruncana morozovae* Vass., *Heterostomella praefoveolata* Mjatl., *Plectina ruthenica* (Reuss), *Sitella laevis* (Beiss.)

Campanian, Late 1

- *Brotzenella monterelensis* Zone: *Ataxophragmium crassum caspium*Vass., *Brotzenella menneri* (Kell.), *Brotzenella monterelensis* (Marie), *Cibicidoides aktulagayensis* (Vass.), *Globatruncana linneiana* (Orb.), *Haterostomella praefoveolata* Mjatl., *Orbignyna sacheri* (Reuss), *Sitella carseyae* (Plumm.), *Voloshinovella lafittei* (Marie).

Campanian, Late, PriAralie

- Cibicidoides aktulagayensis Zone: *Ataxophragmium crassum caspium* Vass., *Orbignyna ovata* Hag., *Voloshinovella laffittei* (Marie), *Heterostomella praefoveolata* Mjatl., *Eponides biconvexus* Marie, *E. frankei* Brotz., *Gavelinella clementiana laevigata* (Marie), *Brotzenella monterelensis* (Marie), *B. taylorensis* (Cars.), *Cibicidoides aktulagayensis* (Vass.), *Globotruncana arca* (Cushm.), *G. morozovae* Vass., *Pseudcuvigerina cristata* (Marss.), *Rugoglobigerina kelleri* (Subb.), *Bolivina kalinini* Vass.

Campanian, Late 2, Turgay

- *Bolivina kalinini-Brotzenella taylorensis* Zone: *Spiroplectammina variabilis* (Neck.), *Plectina ruthenica* (Reuss), *Ataxophragirium compactum* Brotz., *A. spongiosum* Kriv. *A. crassum caspium* Vass., *Orbignyna inflata* (Reuss), *O. sacheri* (Reuss), *Arenogandryina granosa* Podobina, *Nodosaria* spp., *Dentalina* spp., *Valvulinoides umovae* (Kypr.), *Globorotalites emdyensis* Vass., *G. michelinianus* (Orb.), *Gyroidinoides obliquaseptatus* (Mjatl.), *Eponides biconvexus* Marie, *Eponidella* linki Wick., *Gavelinella clementiana* (Orb.) *s.l.*, *Brotzenella taylorensis* (Carsey), *Anomalinoides falsiplanctonicus* (Balakhm.), *Bolivina kalinini* Vass., *B. plaita* Carsey, *Bolivinoides decoratus decoratus* (Jones), *B. laevigatus* Marie, *Globigerinelloides asper* (Ehrenb.), *Heterohelix globulosa* (Ehrenb.).

Campanian, Late 1, Turgay

- *Spiroplectammina optata* Zone: *Bathysiphon vitta* Nauss, *Thurammina papillata* Brady, *Ammodiscus glabratus* Cushm. *et* Jarv., *Haplophragmoides ruidus crispus* Podobina, *H.* cf. *idonensis* Podobina, *Haplophragmium planum* (Belous.), *Spiroplectammina brevis* Kiss., *S. multiversurata* Kiss., *S. kelleri* Dain, *S. optata* Kiss., *Bolivinopsis rosula* (Ehrenb.), *Dorothia pupoides* (Orb.), *Ataxophragmium rimosum* (Marss.), *Valvulineria laevie* Brotz., *Gyroidinoides umbilicatulus* (Orb.), *Osangularia cordieriana* (Orb.), *Eponides sibiricus* Neck., *Cibicidoides eriksdalensis* Brotz., *C. aktulagayensis* (Vass.), *Brotzenella monterelensis* (Marie), *Anomalinoides pinguis neckayae* Vass., *Allomorphina nonioninoides* Dain.

Campanian, Early 3

- *Cibicidoides temirensis* Zone: *Bolivinitella galeata* Vass., *Bolivinoides decoratus decoratus* Jon., *Bolivinoides laevigatus laevigatus* Marie, *Cibicidoides aktulagayensis* (Vass.), *Cibicidoides montanus* (Dol.), *Cibicidoides temirensis* (Vass.), *Eponides biconvexus* Marie, *Gavelinella dainae* (Mjatl.), *Gavelinella stelligera* Marie, *Osangularia cordieriana* (Orb.), *Plectina convergens* (Kell.), *Stensioeina pommerana* Brotz.

Campanian, Early 2

- *Bolivinoides decoratus decoratus* Zone: *Biglobigerinella algeriana* Sig. *et* Ten Dam, *Bolivinoides decoratus decoratus* Jon., *Bolivinoides granulatus* Hofk., *Eponides moskvini* (Kell.), Gavelinella *clementiana pseudoexcolata* (Kal.), *Globigerinalloides volutus* (White), *Orbignyna irreperta* Wolosch.

Campanian, Early 1

- *Gavelinella clementiana clementiana* Zone: *Bolivinoides laevigatus finitimus* Vass., *Dorothia pupoides* (Orb.), *Neoflabellina rugosa* (Orb.), *Gavelinella clementiana clementiana* (Orb.), *Gavelinella dainae* (Mjatl.), *Globigerinelloides asper* (Ehr.), *Globigerinelloides clavatus* Bronn., *Globotruncana arca* (Cushm.), *Neoflabellina rugosa* (Orb.), *Reussella pseudospinulosa* Troels., *Stensioeina pommerana* Brotz.

Campanian, Early PriAralie

- *Cibicidoides temirensis* Zone: *Ataxophragmium orbignynaeformis* Mjatl., *Stensioeina mursatacensis* Vass., *S. pommerana* Brotz, *Eponides moskvini* (Keller), *Osangularia cordieriana* (Orb.), *Gavelinella costulata* (Marie), *G. dainae* (Mjatl.), *G. clementiana pseudoexcolata* Kalin., *Cibicidoides temirensis* (Vass.), *Bolivinoides decoratus decoratus* Jon., *B. laevigatus laevigatus* Marie, *Bolivinitella galeata* Vass.

Campanian, Early Turgay

- *Spiroplectammina senonana pocurica* Zone: *Rhabdammina cylindrica* (Glaessn.), *Bathysiphon nodosariaformis* Subb., *Thurammina splendens* Egger, *T. porosa* Egger, *Glomospira corona* Cushm. *et* Jary., *G. gordialiformis* Podob., *Reophax proprius* Podob., *R. angustus* Belous., *Adercotryma glomeratoformis* (Zasp.), *Haplophragmoides giganteus* Belous., *Cribrostomoides cretaceus exploratus* Podob., *C. trinitatensis sibiricus* Podob., *Labrospira fraseri propensa* Podob., *Ammobaculites fragmentarius* Cushm., *Ammomarginulina crispa* (Kypr.), *Spiroplectammina senonana pocurica* Balakhm., *Trochammina boehmi* Franke, *Gaudryinopsis vulgaris* (Kypr.), *Pseudoclavulinia bastata admota* Podob.

Santonian, Late

- *Gavelinella stelligera* Zone: *Ataxophragmium orbignynaeformis* Mjatl., *Bolivinoides strigillatus* (Chapm.), *Cibicides excavatus* Brotz., *Cibicidoides eriksdalensis* (Brotz.), *Gavelinella costulata* (Marie), *G.* ex gr. *stelligera* (Marie), *G. stelligera* (Marie), *G. umbilicatula* (Mjatl.), *Globorotalites michelinianus* (Orb.), *Globotruncana bulloides* Vogl., *Osangularia whitei crassa* (Vass.), *O. whitei polycamerata* (Vass.), *O. whitei praeceps* (Brotz.), *O. whitei whitei* (Brotz.), *Praebulimina ventricosa* Brotz., *Spiroplectam-mina rosula* (Ehr.), *Stensioeina exculpta exculpta* (Reuss), *Stensioeina exculpta gracilis* Brotz., *S. granulata perfecta* Koch, *Valvulineria mariei* Vass.

Santonian, Turgay

- *Ammobaculites dignus-Pseudoclavulina bastata admota* Zone: *Rhizammina* sp., *Bathysiphon vitta* Nauss, *Psammosphaera laevigata* White, *Saccammina* spp., *Ammodiscus cretaceus* (Reuss), *Reophax inordinatus* Young, *R. guttiformis* Podob., *Haplophragmoides tumidus* Podob., *H. eggeri* Cushm., *Cyclammina flexuosa* Podob., *Labrospira* spp., *Ammobaculites dignus* Podob., *Ammosealaria incultus* (Ehrenb.), *Pseudoclavulina* sp., *P. bastata admota* Podob.

Santonian, Early 2

- *Stensioeina granulata perfecta* Zone: *Cibicides excavatus* Brotz., *Cibicidoides eriksdalensis* (Brotz.), *Prkebulimina ventricosa* (Brotz.), *Spiroplectammina rosula* (Ehr.), *Stensioeina granulata incondita* Koch, *Stensioeina granulata perfecta* Koch, *Valvulineria mariei* Vass.

Santonian, Early 1, upper part of late Coniacian - lower part of early Santonian

- *Stensioeina exculpta exculpta* Zone: *Cibicidoides erikedalensis* (Brotz.), *Gaudryina laevigata* Franke, *Gavelinella infrasantonica* (Balakhm.), *Gavelinella umbilicatula* (Mjatl.), *Spiroplectammina rosula* (Ehr.), *Stensioeina exculpta exculpta* (Reuss), *Stensioeina granulata granulata* (Orb.).

Coniacian, Late 2

- *Stensioeina granulata granulata* Zone: *Eponides*

concinnus planus Vass., *Gavelinella costulata* (Marie), *G. infrasantonica* (Balakhm.), *G. thalmanni* (Brotz.), *Globorotalites michelinianus* (Orb.), *Osangularia whitei whitei* (Brotz.), *Spiroplectammina embaensis* Mjatl., *Stensioeina granulata granulata* (Orb.), *Valvulineria laevis* Brotz.

Coniacian, Late 1

- *Gavelinella costulata* Zone: *Gavelinella costulata* (Marie), *G. infrasantonica* (Balakhm.), *G. thalmanni* (Brotz.), *Osangularia whitei whitei* (Brotz.), *Bolivinita eleyi* (Cushm.), *Spiroplectammina embaensis* Mjatl., *Stensioeina granulata granulata* (Orb.)

Coniacian, Early

- *Gavelinella kelleri* Zone: *Bolivinita eleyi* (Cushm.), *Eponides concinnus* Brotz., *Gavelinella kelleri* (Mjatl.), *G. praeinfrasantonica* (Mjatl.), *Globotruncana renzi* Gand., *Gyroidinoides turgidus* (Hag.), *Reussella kelleri* Vass., *Stensioeina granulata kelleri* Koch, *Verneuilina muensteri* Reuss.

Coniacian, Turgay

- *Haplophragmium chapmani-Ammoscalaria antis-Reussella kelleri* Zone: *Ammobaculites dignus* Podob., *Ammobaculoides unicus* Tanach., *Ammoscalaria antis* Podob., *Haplophragmium chapmani* (Tapp.), *Spiroplectammina senonana orientalis* Kiss., *Trochammina boehmi* Franke, *T. arguta* Podob., *Discorbis sibiricus* Dain, *Reussella kelleri* Vass., *Eponides concinnus planus* Vass., *Gavelinella costulata* (Marie), *G. infrasantonica* (Balakhm.), *Heterohelix* spp.

Coniacian, Zauralie

- *Discorbis sibiricus* Zone: *Arenobulimina* sp., *Nodosaria* sp., *N. zippei* Reuss, *N. hastata* Schar., *Dentalina* sp., *D. basiplanata* Cushm., *D. tineaformis* Schar., *Discorbis* sp., *D. sibiricus* Dain, *Stensioeina emscherica* Baryschn., *Valvulineria lentiouia* (Reuss), *Eponides* sp., *E. incognitus* Kypr., *E. karsteni* (Reuss), *Gavelinella infrasantonica* (Balakhm.), *G. praeinfrasantonica* (Mjatl.), *G. sibirica* Dain, *Cymbalopora martini* (Brotz.), *Reussella kelleri* Vass., *Praebulimina* sp., *Heterohelix* spp.

Coniacian, Early W Siberia

- *Haplophragmium chapmani-Ammoscalaria antis* Zone: *Ammobaculites dignus* Podob., *A. fragmentarius agglutinans* Podob., *Ammobaculoides unicus* Tanach., *Ammoscalaria antis* Podob., *Haplophragmium chapmani* (Tapp.), *Spiroplectammina senonana orientalis* Kiss.

Turonian, Late

- *Gavelinella moniliformis* Zone: *Ataxophragmium compactum* Brotz., *Gaudryina variabilis* Mjatl., *Gavelinella moniliformis* (Reuss), *Globorotalites multiseptus* (Brotz.), *Globotruncana lapparenti* Brotz., *G. marginata* (Reuss), *Hedbergella agalarovae* (Voss.), *Reussella carinata* Vass., *Spiroplectammina praelonga* (Reuss.).

Turonian, Late, W Siberia

- *Pseudoclavulina hastata hastata* Zone: *Ammoscalaria antis* Podob., *Haplophragmoides crikmayi* Stelk et Wall., *H. rota sibiricus* Zasp., *Pseudoclavulina hastata hastata* Cushm., *Textularia anceps* Reuss, *Trochammina arguta* Podob.

Turonian, Early, W Siberia

- *Gaudryinopsis filiformis angusta* Zone: *Ammobaculites tuaevi* Zasp., *Ammomarginulina haplophargoidaeformis* (Balakhm.), *Gaudryinopsis filiformis angusta* Podob., *Haplophragmium incomprehensis* (Ehrem.), *Labrospira collyra* (Nauss.), *Lituotuba confusa* Zasp., *Trochammina subbotinae* Zasp., *Uvigerinammina manitobensis* (Wick.).

Cenomanian, Upper, W Siberia

- *Trochammina wetteri-Trochammina subbotinae* Zone: *Ammobaculites tuaevi* Zasp., *Neobulimina subcretacea* (Cushm.), *Reophax inordinatus* Young, *Saccammina scruposum* Berth., *Thurammina papillata* Brady, *Trochammina subbotinae* Zasp., *T. wetteri* Stelk & Wall, *Uvigerinammina manitobensis* (Wick.).

Cenomanian, Lower and Middle

- *Gavelinella cenomanica* Zone: *Gavelinella bal-*

tica (Brotz.), *G. cenomanica cenomanica* (Brotz.), *G. cenomanica concava* (Vass.), *Globigerinelloides bentonensis* (Morr.), *G. ultramicrus* (Subb.), *Gyroidinoides nitidus* (Reuss), *G. subconicus* (Vass.), *Hagenowella chapmani* (Cushm.), *Hedbergella caspia* (Vass.), *Hoeglundina postdorsoplana* (Vass.), *Lingulogavelinella bilamellosa* (Balakhm.), *Valvulineria lenticula lenticula* (Reuss), *V. lenticula plummerae* Loett.

RADIOLARIA

Turgay

- *Orbiculiforma renillaeforniis* Zone: *Orbiculiforma renillaeformis* (Camp. *et* Clark), *O. australis* Pess., *O. regis* Pess., *Crucella espartoensis* Pess., *Tholodiscus fresnoensis* (Forem.), *Stichocapsa asymbatos* (Forem.), *Dictyomitra* spp.
- *Amphipyndax stocki* Zone: *Spongotrochus morenoensis* Camp. *et* Clark, *Orbiculiforma maxima* (Lipm.), *Phaseliforma subcarinata* Pess., *Patellula verteroensis* (Pess.), *Amphibrachium mucronatum* Lipm., *Prunobracchium articulatum* (Lipm.), *Amphimenium sibiricum* Lipm., *Theocampe sibirica* Lipm., *Amphipyndax stocki* (Camp. *et* Clark), *Dictyomitra* spp., *Lithostrobus rostovzevi* Lipm.
- *Prunobrachium crassum* Zone: *Spongopyle insolita insolita* Kozur., *Spongotrochus polygonatus* (Camp. *et* Clark), *Prunobrachium crassum* (Lipm.), *Amphibrachium ornatum* Lipm., *Porodiscus cretaceus*. Camp. *et* Clark, *Botryometra amazon* (Forem), *Throcampe animula* (Gorb.), *Immersothorax marinas* (Gorb.), *Dictyomitra* spp., *Lithostrobus rostovzevi* Lipm.
- *Ommatodiscus mobilis* Zone: *Phaseliforma concentrica* (Lipm.), *Ommatodiscus mobilis* Kozl., *Spongodiscus* spp., *Orbiculiforma* spp., *O. multa* (Kozl.), *Stylarta longispina* Squin., *Dictyomitra striata* Lipm., *D. torquata* Forem.
- *Stichocapsa pyramidata* Zone: *Cenosphaera* sp., *C. magna* Grig., *Ellipsoxiphus asper* Ruest, *Trochodiscus spiniger* Lipm., *Spongodiscus* spp. *Orbiculiforma* spp. *Stylotrochus dolichacantus* Lipm., *Stichocapsa* sp., *St. pyramidata* (Grig.), *Dictyomitra* spp.
- *Cenodisous cenomanicus-Stichocapsa ferosia uvatica* Zone: *Cenodiscus cenomanious* Aliev, *Triadiscus lozyniaki* Amon, *Pentinastrum kurganicum* Amon, *Spongotripus aculeatus* Lipm., *Stichocapsa* sp., *St. ferosia uvatica* Amon, *Cryptamphorella conara* (Forem.), *Holocryptocanium barbui* Dumitrica.

SPORES-POLLENS ASSOCIATIONS

Maastrichtian, SPA IV.6:

- dominants: *Pinaceae*, *Taxodiaceae*, *Nermapolles* Pf., *Trudopollis* Pf., *T. nonperfectus* Pf., *T. speciosus* Pf.;
- subdominants: *Gleichenidites* sp., *Pinus* sp., *P. aralica* Bolch., *Concavisporites* sp., *Matonisporites* spp., *Polypodiisporites* Ep., *Laevigatosporites* sp., *Cyathidites* sp., *Cedrus* sp., *Casuarinidites* sp., *Triorites* sp., *Triporopollenites* sp., *Betulaepollenites* sp., *Kuprianipollis* sp., *Oculopollis* sp., *Plicapollis sp.*;
- attendants: *Classopollis* sp., *Gnetaceapollenites* sp., *Ephedrites* sp., *Triporopollenites mutabilis* (N. Mtch.) Bratz., *T. radiatostriatus* (N. Mtch.), *Triatriopollenites exelsus* (R. Pot.), *T. rurensis* Pf., *Subtriporopollenites anulatus* Pf., *Vacuopollis* spp., *Nudopollis* Pf., *Extratriporopollenites* Pf., *Mancicorpus* N. Mtch., *Aquilapollenites* Rouse *et* N. Mtch., *Proteacidites* Cook. *et* Coup., *Triprojectus* N. Mtch.;
- microphytoplankton abundant.

Campanian, SPA IV.5:

- dominants: *Gleicheniidites senonicus* Ross., *G. laetus* (Bolch.) Bolch., *Plicifera delicata* (Bolch.) Bolch., *Pinus* sp., *P. aralica* Bolch.;
- subdominants: *Concavisporites* sp., *Matonisporites* sp., *Polypodiisporites* sp., *Laevigatosporites* sp., *Cyathidites* sp., *Ariadnaesporites verrucatus* (Elsik) Hills., *Cedrus* .sp., *Casuarinidites* sp., *Triorites* sp., *Triporopollenites* sp.l *Betulaepollenites* sp., *Kuprianipollis* sp., *Trudopollis rector* Pf., *T. hemiperfectus* Pf., *T. parvotrudens* Pf., *T.* sp., *Oculopollis* sp., *Plicapollis serta* Pf., *P. conserta* Pf., *P.* sp.;
- attendants: *Appendicisporites* sp., *Cicatricosisporites* sp., *Hemitelia* sp., *Balmeisporites* sp., *Vacuopollis* spp., *Nudopollis* Pf., *Extratriporopollenites* Pf., *Postnormapolles* Pf., *Manci-*

corpus N. Mtch., *Aquilapollenites* Rouse *et* N. Mtch.;
- rare: *Camarozonosporites* Kr., *Taurocusporites reduncus* (Bolch.) Stover, *Stenozonotriles radiatus* Chl., *Divisisporites eukirchenensis* Th., *Foraminisporis barangaensis* (Nagy) Pacl.;
- microphytoplankton abundant.

Santonian, SPA IV.4:
- dominants: *Gleicheniidites senonicus* Ross., *G. laetus* (Bolch.) Bolch., *Plicifera delicata* (Bolch.) Bolch., *Pinus* sp., *P. aralica* Bolch., *Cedrus parvisaccata* Sauer, *C. pisilla* Sauer;
- subdominants: *Concavisporites* spp., *Matonisporites* spp., *Polypodiisporites flexus* Chl., *Laevigatosporites ovatus* Wils. *et* Webst., *Cyathidites australis* Coup., *C. minor* Coup., *C. punctatus* Delc. *et* Sprum., *Cedrus pachiderma*. Sauer, *Taxodiaceae*, *Casuarinidites cainozoicus* Cook. *et* Rike, *Triorites harrisii* Coup., *Triporopollenites plicoides* Zakl., *Betulaepollenites microexelsus* P. Rot., *Scabratricolpites legibilis* Samoil., *Kuprianipollis santaloides* (Stelm.) Kom., *K. elegans* (Zakl.) Kom., *Complexiopollis* spp., *Vacuopollis* spp., *V. pyramis* Pf.;
- attendants: *Appendicisporites* sp., *Cicatricosisporites* sp., *Hemitelia mirabilis* Bolch., *H. separata* Chl., *H.* sp., *Balmeisporites ratus* Kond., *B. striatus* Kond., *B.* sp., *Thomsonipollis magnificus* (Th. *et* Pf.) Kr., *Concavipollis* Pf., *Multiporopollenites* sp., *Bombacacidites* sp., *Liliacidites* sp., *Monocolpites* sp., *Symplocacites* sp., *Proteacidites* sp., *Triporopollenites* sp., *Trudopollis* sp.;
- rare: *Camarozonosporites* Kr., *Taurocusporites reduncus* (Bolch.) Stover, *Stenozonotriletes radiatus* Chl., *Divisisporites eukirchenensis* Th., *Foraminisporis barangaensis* (Nagy) Pacl.;
- microphytoplankton abundant.

Turonian, SPA IV.3:
- dominants: *Gleiheniidites* spp., *Selaginella* spp., *Plicifera delicata* (Bolch.) Bolch., *Pinaceae*;
- subdominants: *Taurocusporites reduncus* (Bolch.) Stover, *Cyathidites australis* Coup., *C.* spp., *Hemitelia maxonii* Ros., *Matoniasporites* spp., *Lygodium*. spp., *Contignisporites perplexus* Sind., *Laevigatosporites ovatus* Wils. *et* Webst., *Polypodiisporites flexus* Chl., *Retitricolpites* spp., *Tricolpites* cf. *reticulatus* Cook., *T. erugatus* Hedl. *et* Norris, *Quercites sparsus* (Mart.) Samoil., *Araliaceae*, *Rutaceae*, *Nyssapollenites* sp., *Polyporites clarus* N. Mtch., *Monocolpites bisulcus* Mart., *Liliacidites* sp., *Disulcites reticulatus* Pot., *Ericipites* sp.;
- attendants: *Camarozonosporites ratus* Kr., *C.* spp., *Concavisporites kainophyticus* Voron., *C. junctum* (K.-M.) Semenova, *Kornilovites crispus* Kalm., *K. trisegmentatus* Kalm., *Cicatricosisporites perforatus* (Mart.) Voron., *C. exilioides* (Mal.) Voron., *C. dorogensis* Pot. *et* Cell., *Appendicisporites* sp., *Anemia* sp., *Complexiopollis* Pf., *Kuprianipollis* Kom., *Turonipollis* Ameron, *Tricolporopollenites* Pf., *Triarites*;
- microphytoplankton rare.

Late Cenomanian-early Turonian, SPA IV.2:
- dominants: *Gleiheniidites* sp., *G. senonicus* Ross., *G. laetus* (Bolch.) Bolch., *G. stellatus* (Bolch.), *Plicifera delicata* (Bolch.) Bolch., *Pinaceae*;
- subdominants: *Cyathidites australis* Coup., *C.* spp., *Hemitelia maxonii* Ros., *Matoniasporites* spp., *Lygodium* sp., *L. japoniciforme* E. Iv., *L. granulatum* E. Iv., *Contignisporites perplexus* Sing., *Laevigatosporites ovatus* Wils. *et* Webst., *Polypodiisporites flexus* Chl., *Retitricolpites vermimurus* Brenn., *R. granosus* Hedl. *et* Norris, *R. vulgaris* Pierce, *Tricolpites* cf. *reticulatus* Cook., *T. erugatus* Hedl. *et* Norris, *Rousea micilipollis* Srivast., *Viburnum* sp., *Quercites sparsus* (Mart.) Samoil., *Araliaceae*, *Rutaceae*, *Nyssapollenites* sp., *Polyporites clarus* N. Mtch., *Monocolpites bisulcus* Mart., *Liliacidites* sp., *Disulcites reticulatus* Pot., *Ericipites* sp.;
- attendants: *Camarozonosporites ratus* Kr., *C.* spp., *Concavisporites kainophyticus* Voron., *C. junctum* (K.-M.) Semenova, *Kornilovites crispus* Kalm., *K. trisegmentatus* Kalrm., *Cicatricosisporites perforatus* (Mart.) Voron., *C. exilioides* (Mal.) Voron., *C. dorogensis* Pot. *et* Cell., *Appendicisporites* sp., *Anemia* sp., *Complexiopollis* Pf., *Kuprianipollis* Kom., *Turenipollis* Ameron, *Tricolporopollenites* Pf., *Triarites* sp.;

- rare: *Taurocusporites reduncus* (Bolch.) Stover, *T. segmentatus* Stover, *Foraminisporis wonthagiensis* (Cook. *et* Dettm.) Dettm.;
- microphytoplankton rare.

Early-middle Cenomanian, SPA IV. 1:
- dominants: *Gleiheniidites* sp., *G. senonicus* Ross., *G. laetus* (Bolch.) Bolch., *Pinus*, *Cedrus*, *Podocarpus*, *Dacridium*., *Phyllocladites*;
- subdominants: *Dicksoniaceae*, *Cyatheaceae*, *Matoniaceae*, *Polypodiaceae*, *Lygodium* sp., *L. japoniciforme* E. Iv.;
- attendants: *Lophotriletes*, *Hymenozonotriletes*, *Camarozonosporites*, *Concavisporites*, *Cicatricosisporites* sp., *Appendicisporites* sp., *Anemia* sp., *Castanea vakhraneevi* Bolch., *Tricolpites sagax* Norris, *T. albiensis* Kemp., *Cipuliferoidaepollenites minutus* (Brenner) Sing., *Platanus orientaliformis* Samoil., *Menispermum turonicum* N. Mtch., *Quercites sparsus* (Mart.) f. *vescus* Samoil., *Rhamnaceae* ;
- rare: *Cinguulatisporites eukirchensoides* Delc. *et* Sprum., *Taurocusporites reduncus* (Bolch.) Stover, *Peromonolites reticulatus* Brenner, *Typha* sp.

FLORA

Leafy flora assemblage LFA I:
- *Asplenium dicksonianum* Heer, *Onychiopsis psilotoides* (St. *et* Webb) Ward, *Gleichenia* sp., *Cladophlebis foergeissenii* (Heer) Vachr., *C. kuldensis* Vachr., *Sphenopteris* sp., *Nissonia kazachstanica* Vachr., *Otozamites jarmolenkoi* Vachr., *Zamites* ? sp., *Podosamites ellipsoides* Sap., *Sequoia heterophylla* Velen., *S. fastigata* Heer, *Magnolia* sp., *Menispermites kryschtofovichii* Vachr., *Myrica* ? *kuldensis* Vachr., *M. zenkeri* (Ett.) Heer., *Platanus pseudoguillelmae* Krass., *P. cuneiformis* Krass, *P. golenkinii*, Vachr., *P. primaeva* Lesq., *P. newberryana* Heer., *Dalbergites sewardiana* (Shap.) Vachr., *D. simplex* (Newb.) Sew., *Leguminosites ovalifolius* Heer, *Acer janschinii* (Vachr.) Vachr., *Ziziphus menneri* Vachr., *Vitis cretacea* Vachr., *Cissites uralensis* Krysht., *Aralia formosa* Heer, *Diospyros primaeva* Heer, *Dicotylophyllum rhomboidale* Vachr.

Aktyubinskian Priuralie, Western Primugodzharie, Upper Albian-Cenomanian.

So called Koldenen-Temirskian flora (according to Shilin, 1986).

Leafy flora assemblage LFA II:
- *Regnellidium* sp., *Taxites kasachstanica* Shilin, *Magnollia alternans* Heer, *M. amplifolia* Heer, *Laurophyllum* sp., *Platanus* sp., *P. pseudoguillelmae* Krass., *P. cuneiformis* Krass., *Celtidophyllum praeustrale* Krass., *Dalbergites simplex* (Newb.) Sew., *Ilex* sp., *Ziziphus ajatensis* Vachr., *Diospyros primaeva* Heer, *Eucalyptus uralensis* Vachr.

Turgay trough, Cenomanian-Turonian.

Mesozoic radiolarians from the European Platform: a review

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ABSTRACT
This paper is primarily concerned with providing an overview of studies on Mesozoic radiolarians and presents a general background of living radiolarians and the different stages they go through (the filters) from their state as plankton to their state as fossils, as geologists find them in rocks. This is followed by a review of the main publications documenting radiolarians worldwide since their discovery. The main purpose of this paper is to present to westerners the various work related to the eastern European platform countries (European part of the former Soviet Union) as the majority of these papers are written in languages unfamiliar to most geologists. We have therefore chosen to present here their historical background, and their location, as precisely as possible, in order to allow further comparisons.

KEY WORDS
radiolarians,
Peritethys,
Mesozoic,
Silica,
plankton.

RÉSUMÉ
Nous présentons ici un survol des études ayant porté sur les radiolaires mésozoïques. Nous nous intéressons d'abord au contexte général des radiolaires en tant qu'organismes vivants et aux étapes qu'ils franchissent (les filtres) depuis leur état d'organisme planctonique jusqu'à leur état de fossiles, tels que le géologue les rencontre dans les roches. On envisage ensuite les principaux travaux à travers le monde permettant de mieux les connaître, depuis leur découverte. Le principal but de cet article est de mettre à la disposition de la communauté occidentale les résultats portant sur la partie orientale de la plate-forme européenne (partie européenne de l'ex-Union Soviétique), ces travaux étant le plus souvent difficile d'accès à la plupart des géologues. Nous avons donc choisi de présenter ici leur contexte historique, et leur localisation, aussi précisément que possible, afin de permettre leur utilisation et des comparaisons ultérieures.

MOTS CLÉS
radiolaires,
Péritéthys,
Mésozoïque,
Silice,
plancton.

INTRODUCTION

Stratigraphical correlation has been hampered by lack of world-wide cooperative studies. Now that scientific exchange is easier between Eastern and Western workers the solutions to many stratigraphic problems may be found through joint projects and enable researchers to compile a more complete fossil record. Improved networking can now allow interested workers to develop models that will facilitate more accurate interpretations of geological basins. The goal is to make biostratigraphical basin analyses a more useful tool both for industry and for academics. Some fossil groups have been studied for a long time, are relatively well known and their correlations between several basins are possible, even though still imperfect. On the contrary, other fossil groups remain almost ignored with potentially important groups often overlooked as stratigraphic tools. The utility of these groups is excellent when systematic conformity is applied by the specialist communities. The changing relationship of some fossils groups with other groups often signals changes in basin and oceanographic conditions. Taxonomic and stratigraphic syntheses are published or in preparation from Tethyan regions but often no correlation is possible with geographical areas which were under Boreal influence. This gap in our knowledge results from: (1) different palaeogeographic domains (Boreal *vs* Tethyan); (2) the fact that much of the Boreal data was acquired in eastern countries where methods and technical means are different (*i.e.* no common use of the scanning electron microscope). Comparisons between the relevant fossil assemblages are problematical partly because of the inaccessibility of much of the published literature, especially in reference to the taxonomy, and partly because of the lack of good photographic illustrations in the published monographs.

In order to progress towards the correlation between Boreal and Tethyan basins it is first necessary to standardise the different biological chronometers of the existing studies available. The objective is to consolidate information so that other geologists interested in these deposits can use the interrelationship of microfossils as a valuable tool. Other indirect benefits are to be able to understand Russian terminology in translation, and eventually, standardise terms. Our project will be accomplished by developing a three-fold process, each part of which can be carried out simultaneously. Firstly a state of the knowledge has to be settled: this is the objective of the present paper. Secondly the systematics must be dealt with (re-examination of the taxonomy of some selected fossil groups from western basins and from the Russian Platform, Caspian Sea Region, Siberian Lowlands, North Kazakhstan, ... which have been worked on by many specialists). Thirdly, to develop biostratigraphical and palaeoenvironmental application by comparisons of lithology, geologic history, abundance and diversity with other fossils. This enormous task will then allow problems to be jointly stated and solutions to be recorded.

To extrapolate the original biological environmental signals from the geological features recorded requires a good knowledge of (i) successive filters which have changed it and of (ii) the originators of these signals (*i.e.* the radiolarians). Radiolarians have existed since the Cambrian (Nazarov & Ormiston 1993) and comprise several thousand species. They were disregarded for stratigraphic purposes for a long time, but since Riedel (1952, 1957) proved their stratigraphical worth, they have been studied more thoroughly, especially since the 1980's and their high value is now established. Because of the difficulty extracting radiolarians from siliceous rocks, the first zonations were only proposed for the Cenozoic and the Mesozoic during late 1970's (beginning with the Cretaceous then the Jurassic and later for Triassic times) and for the Palaeozoic since the 1980's.

INTERPRETATION OF OBSERVATIONS

The initial stratigraphic problems were due to the initial taxonomy which used an unnatural taxonomic system and which did not reflect phyletic relationships. This phase in the progress of Cenozoic radiolarian taxonomy and stratigraphy has depended largely on material collected. As more natural groupings replace the artificial ones

of Ehrenberg and Haeckel, genera and families that extend from Palaeozoic to Mesozoic, or from Mesozoic to Cenozoic, become the peculiarity rather than the rule (Riedel 1967b). The Haeckelian system of radiolarian classificarion now persists in use only to the extent that the arduous task of the tracing of phyletic relationships remains incomplete. Disputable taxonomy for some radiolarians hampers the registering of assemblages in their entirety, at the level of species. many taxa are variously delimited by different authors, so that a work has little utility unless it describes and illustrates (or refers to a published, illustrated description of) the morphological variability involved for each name. A perplexing decision to be required, at the beginning of an investigation of radiolarian strarigraphy, is the extent to which it is appropriate to quantify abundances of taxa. It is generally unsatisfactory to record only presences and absences, because the observation of hundreds of specimens of a taxon in an assemblage clearly carries more weight in interpretations than does a single specimen. And an absence recorded after searching through few specimens has less meaning than one recorded after searching through ten thousand. On the other hand, it can be a futile effort to count abundances with great precision, unless detailed palaeoenvironmental interpretations are the main goal. When thousands of specimens are present on each slide, as it is commonly the case in Cenozoic radiolarian studies, it is possible ro conduct a middle policy between excessive and insufficient quantification by estimating how many specimens must be searched through, to find a certain number of specimens of the taxon being recorded, and then converting this number to a ratio of the total assemblage. The resulting estimates of abundance are useful not only for the weighting of biostratigraphic events but also for broad-scale palaeoenvironmental indications. Preservation of the radiolarians is another important factor in stratigraphic interpretations, for the recording of which there are not, as yet, any satisfactory conventions. It is not unusual for authors to record assemblages as "well *vs* poorly preserved", "slightly *vs* greatly corroded", etc., and these indications are useful in evaluating the significance of absences of delicate species from the assemblages, or concentrations of particularly robust species.

From plankton to rock

Radiolarians, present in all oceans and open seas, are floating predators and include in their cytoplasm symbiotic algae (zooxanthellae) which also contribute to their nutrition. Several groups of radiolarians have a high endoplasmic content of oil-droplets. A connection with volcanism, which has always been presumed, is erroneous. Radiolarians live in the upper part of the water column and do not require a deep ocean. A laritudinal distriburion does exist for radiolarian associations. Ir is also possible to differentiate surface from subsurface assemblages. In sediments below upwelling sites a mixture of fauna systemarically occurs: cold and warm-water species as off Peru where Anrarctic waters are mixed with tropical waters (De Wever *et al.* 1995, NAUTIPERC), surface and subsurface waters as off Somalia (Caulet *et al.* 1992). Hence, the chances of distinguishing Tropical-Tethyan as against Boreal fauna when working on fossil radiolarians extracted from radiolarite are almost non-existent since radiolarite facies result from upwelling systems (De Wever *et al.* 1994, elf). It is therefore necessary to investigate radiolarians from other facies to be able to depict bioprovinces and the sediments of the Russian platform, having both Tethyan and Boreal influences, are good candidates. Polycystines (a Superorder), with their siliceous skeleton, are the only radiolarians *s.l.* which are preserved as fossils. At present, among Polycystines, the order of Nassellarians are the most diversified, although those of the order of Spumellarians seem to be the most abundant (Lombari & Bowden 1982).

After death, an individual test is at least partially dissolved during its settling through the water column, then while ir lies on the sea floor and finally within the sediment. Most of the radiolarians that settle occur in faecal pellets. Sediments deposited at the same time as the biota tend to average out the background variations such as seasonal changes. Robust forms and those of blooms are over-represented in sediments when

compared with the common plankton (Swanberg & Bjørklund 1992). The numbers of individuals and species are lower in sediment (and *a fortiori* in the rock) than in plankton. It is estimated that less than 1% of the silica fixed by planktonic organisms in surface waters is preserved within the geological record. This difference is greater when planktonic individuals are not abundant. Radiolarians may be abundant in relatively shallow basins close to a shoreline where prevailing chemical conditions favour their preservation and where detrital input is very low, *e.g.* the Santa Barbara Basin, off California at a depth of below 500 m (Kling 1979). Other examples can be quoted in Norwegian fjords (Swanberg & Bjorklund 1992). Abundant radiolarians and foraminifers frequently share the same geographical water domains but in sediments they are often mutually exclusive: when siliceous fossils are preserved, calcareous ones are not and *vice versa*. Radiolarians behave as other planktonic organisms: the most important factor being the abundance of nutriments, not the abundance of silica. A scenario where transgressions are associated with a significant input of organic matter and a radiolarian bloom has been proposed by Steinberg (1981) for the main epochs of silica deposition.

The biogenic silica Opal-A is unstable and transformed into Opal-CT then into quartz. Transformations from opal to quartz are separated by a liquid stage (Carr & Fyfe 1958; Mizutani 1966). Temperature and time strongly affect silica diageneric phases (Murata & Larson 1975). Hence, chert prevails in older or deeper sediments and porcelanites in younger or shallower ones. Silica phase transformations are accompanied by porosity reduction. The original porosity is higher when the sediment is richer in silica and during diagenesis (Isaacs 1981). For the geologist, the porosity decrease (volume) corresponds to a diminishing of only one dimension (the thickness) and the important decompacting factor has to be taken into account when accumulation rate and palaeoproductivity calculations are made (De Wever *et al.* 1994). In addition to pressure and temperature, time favours both opal transformations. Cherts thus are more prevalent in older sediments (Palaeozoic and Mesozoic) and porcelanites in more recent ones (Cenozoic). The transformation of Opal-A to Opal-CT is estimated to occur at 25-50° and takes 20 m.y. in areas of low to moderate sedimentation rates and 5-10 m.y. in areas of high sedimentation rates (Kastner 1981). The Opal-CT to quartz transformation occurs within 40-50 Ma (Keene 1976). All the possible modifications which affect a radiolarian test (dissolution in the water column, near the sediment-interface and during diagenesis) after its death are so great that the chances for a skeleton to be observable by a geologist are almost zero, especially when one adds the etching with hydrofluoric acid to free the test from the rock in the laboratory.

Potential importance of radiolarian contribution to marine petroleum source rocks

As shown by Lisitzin (1971), those areas in modern oceans that have high organic productivity are invariably rich in diatoms and/or radiolarians, and these are deposited in the bottom sediment. Primary production of organic matter in the present-day marine environments is mainly assumed by various group of unicellular, microscopic planktonic organisms. Radiolarians were probably an important producer during Palaeozoic and early Mesozoic times when planktonic foraminifers, coccoliths and diatoms had not emerged (Ormiston 1993). Production of biogenic silica and marine organic matter both result from a high planktonic activity (Takahashi 1986; Diester-Haass *et al.* 1992; Caulet *et al.* 1992; Sarnthein *et al.* 1992) but do not always remain associated in sediment (De Wever & Baudin 1996).

Some source rocks have their kerogen present as structureless, amorphous material not attributable to any specific organism. It is not uncommon, however, to read references to such structureless amorphous material as being of "algal" origin despite a lack of rigorous proof. It is suggested by Ormiston (1993) that radiolarians, which are a common biotic element in source rocks, could have contributed significantly to their organic richness as they are known to

contain significant concentrations of lipids, even though the identity of those lipids remains a mystery. A steady contribution of radiolarian lipids to ocean sediments could have been mediated by the minute faecal pellets (minipellets 10 to 30 µm in size) these organisms have recently been found to produce (Gowing & Silver 1985). The main biochemical components of radiolarians consist of carbohydrates, protein and lipids, the latter being an important component of organic molecules accreted in the sediment. Certain colonial radiolarians are particularly lipid-rich (Anderson 1983). The organic carbon content of such colonial radiolarians is, naturally, high. If this lipid-rich material accretes in substantial amounts in oceanic sediment, it ought to be a significant contributor to organic richness of those sediments. Some modern colonial species which are lipid-rich (see illustrations *in* De Wever 1994) and have a preservable skeleton are abundant at certain times of the year in oceanic waters. Calculation reveals a significant potential contribution of lipid input to modern ocean sediments by colonial radiolarians. We can reasonably infer that ancient radiolaria also contained substantial lipid-rich vacuoles as these are so important, both as a food resource and as an aid to flotation. Radiolarians are predators and feed from a diverse range of food sources (Swanberg & Anderson 1985) which suggests that they would have access to such a selection of molecules that their biochemical make up might be highly varied. Moreover, their symbionts contribute to an important extent to the lipid droplets included in their central capsula, either directly or indirectly (Anderson 1983). The directness of the pathway from these symbiotic algal cells to the lipid dropler of radiolarians suggests that those lipid droplets in radiolarians might have molecules with an "algal signature". Research is still needed to recognise possible biomarkers in living radiolarians. The identification of a diagnostic radiolarian would not only provide a means to identify radiolarian contribution to lipid-richness of ancient sediment. At least until such chemical evidence is available one should include palaeontological study of body fossils in any study attempting palaeoenvironmental characterisation of such sedimentary rocks because of several factors: (1) silica may act as a dilutent of the organic matter (Bogdanov *et al.* 1980; Aplin *et al.* 1992); (2) porosity has an important role in the preservation or otherwise of the organic matter, permitting exchanges, oxygenation or action of sulphates which destroyed it (Aplin *et al.* 1992). To conclude, there is a relation between organic matter and silica but there is more than one parameter that influences their abundance in sedimentary rocks and these factor's identity and importance are not well identified yet. They both result from a high productivity but, as their conditions of preservation are not the same, they are not systematically associated in sedimentary rocks. It would now be of great interest to compare these Mesozoic depositional sites with some other related facies such as phtanites of Western Europe.

HISTORICAL BACKGROUND

In order to present a general scope of the studies, we have chosen to address the general state of world-wide knowledge, with special emphasis on Europe, before providing all the information from Russian platform in a more detailed form.

Although Ehrenberg (1854-1856) had sufficient marine sediments and land-based samples to provide a general portrait of Cenozoic radiolarians, he did not possess good Mesozoic samples. Consequently it was Zittel (1876) who described the first few Cretaceous radiolarians from northern Germany. At about the time that Haeckel (1881, 1887) was publishing his taxonomic system of radiolarians collected by the *Challenger* Expedition, Rüst (1885, 1898) was working on a broadly based investigation of European Mesozoic and Palaeozoic assemblages. Rüst applied Haeckel's generic names, initiated for Cenozoic radiolarians, to his pre-Cenozoic forms. An unfortunate consequence is that many of the genera introduced by Haeckel in 1881 have, as type species, Mesozoic forms described by Rüst (1885) from poorly preserved assemblages, because Haeckel's descriptions of species did not materialize until 1887. Accordingly many of Haeckel's genera are not as firmly based

as they would have been with well-preserved Cenozoic forms as their type species, and a tendency was initiated for Cenozoic and Mesozoic forms to be assigned to the same genus, encouraging an impression that radiolarian genera have long stratigraphic ranges. During the following decades, Cretaceous radiolarians were described from many scattered localities (Table 2), but there was little stratigraphic progress because of the unnatural taxonomic system used. In an effort to overcome this obstacle, Hinde (1897, 1900) began to expand the remark by Rüst (1892) that Mesozoic radiolarian assemblages include higher ratio of cyrtoid species than do Palaeozoic ones. Although this method of approximate age determination was questionable, as was underlined by Tan in 1931, it was still being used, in a somewhat elaborated way, for example, by Kobayashi & Kimura in 1944. Reports of the end of the 19th century are essentially descriptive, and the studied samples are often undated because the absence of any other fauna. The modern phase of Mesozoic radiolarian stratigraphy started with Khabakov (1937), who understood that the seemingly extended stratigraphic ranges of many taxa were the repercussion partly of the unnatural taxonomic system, and partly of mistaken age-determinations of strata. Researchers used Haeckelian systematics for decades (*e.g.* Campbell & Clark 1944; Campbell 1954). Since the work by Riedel on Cenozoic material (1952, 1953) revealed the Haeckelian system inappropriate, it became clear that the taxonomic system for Mesozoic radiolarians would have to be reconsidered and that it is disjunct from that for the Cenozoic (Riedel 1967b). Indications for a sudden change in fauna at or near the Cretaceous/Paleocene boundary are documented by Lipman (1952) and Foreman (1968) resulting in ensuing large numbers of new genera and several new families being described for the Mesozoic (Foreman 1968; Dumitrica 1970; Pessagno 1969a, b, ...). During the 1960's, some stratigraphic charts were published for Cretaceous radiolarians, but these were generally of local applicability. Zhamoida (1972) compiled a summary of Mesozoic radiolarian occurrences in the "Pacific mobile belt", and Zhamoida & Kazintsova (1981) reviewed Mesozoic radiolarian literature appearing between 1967 and 1978. In the 1970's, the Deep Sea Drilling Project (DSDP) afforded the chance to correlate the evidence between continental and marine localities, making possible the construction of stratigraphic charts of wide applicability, and also allowing the calibration of radiolarian occurrences with calcareous microfossil groups zonations.

TRIASSIC

Despite the great diversity existing among Upper Norian and Rhaetian radiolarians, relatively few taxa have been described.

World (excluding Europe)

Pacific, Atlantic, Indian. None.

America. Some earlier studies in North America were published by: Martin *et al.* 1915, and Smith 1916. A new set of studies was initiated on western North America by Pessagno *et al.* (1979) in Baja California. Pessagno & Blome (1980) studied the evolution of pantanelliid radiolarians and described species of several other genera from the upper Norian on Queen Charlotte Islands. Blome (1984a, b) further studied this fauna, described new species and proposed a preliminary radiolarian zonation for the Upper Triassic of western North America with the topmost Triassic subzone, the Betraccium deweveri Subzone, based on upper Norian faunas of Monotis age from the same locality. Further investigations in the Queen Charlotte Islands were undertaken by Carter (1990, 1993) who also studied the diverse Rhaetian fauna from the Sandilands Formation and proposed three preliminary radiolarian assemblages. Subsequent studies have included documentation of the Triassic-Jurassic boundary in northern Queen Charlotte Islands (Tipper & Carter 1990), evolutionary trends in latest Triassic and earliest Jurassic faunas (Carter 1994; Tipper *et al.* in press) and a phylogenetic study of the genus Fertesium (Carter 1992). In the northern Cache Creek Terrane of southern Yukon, Canada, upper Norian radiolarians have been reported from a chert sample by Cordey *et al.* (1991).

Elsewhere in western North America, Blome, Reed & Tailleur (1989) found upper Norian radiolarians. Yeh (1989) studied radiolarians in

the upper part of the Fields Creek Formation, east-central Oregon. His fauna (sample FC35) is suggested to be Lower Jurassic, but it compares closely with radiolarians from the Sandilands Formation and is more likely Rhaetian according to Carter (1993) who described and illustrated much of the Rhaetian fauna of the Queen Charlotte Islands.

SE Asia (Japan, Indonesia). In Indonesia Hinde (1908) investigated well-preserved radiolarians from a number of Moluccan localities (notably on Roti and Savu) which he believed to be Triassic, and described some eighty species, predominantly spherical and elliptical forms, multi-segmented cyrtoids, together with some closed cyrtoids and three-armed spongy forms. Brouwer (1921) believed this assemblage to be Late Jurassic. In the Phillipines, more recently Cheng (1989) illustrated upper Norian radiolarians from bedded chert of Uson Island. Further studies in this atea by Yeh (1990; 1992) and Yeh & Cheng (1996) indicate that, in addition to faunas of late Ladinian and late Carnian age, two radiolarian assemblages dated as late Norian and

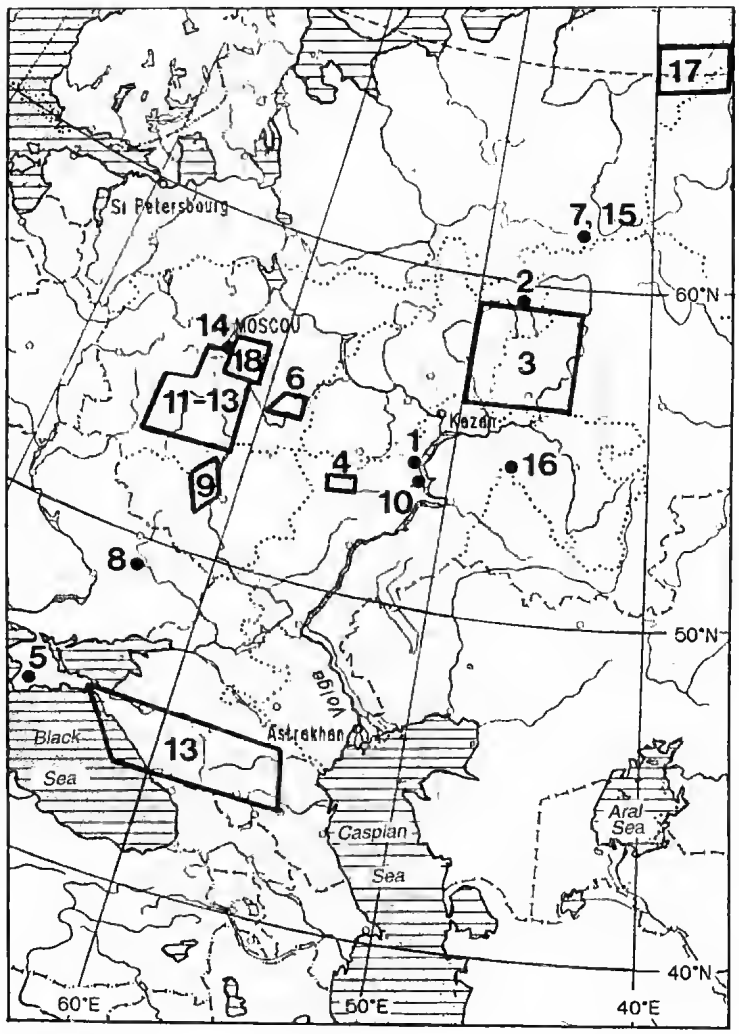

Fig. 1. — General map of eastern Peri-Tethys domain showing the investigated regions listed on table 1. Main areas of investigation are marked with zones. The numbers refer to those given on table 1. Detail maps are provided on Figs 2, 3.

TABLE 1. — List of publications dealing with Mesozoic strata of the Russian platform. Each publication has a number which corresponds to that on figures 1-3. For each publication, the age, region, latitude and longitude, subject of investigation, paleoenvironment and other involved fossil groups are provided.

n°	Author	Age	Region	Longitude Latitude	Subject of investigation	Paleoenvironment	Other group of fossils
1	Kariski 1889 *in* Petrushveskaya 1986 p.144	K2 st	Simbirsk (Uljanovsk)	48°15'E, 54°25'N	Presence of rads was established	Rads ooze from "santonian clay"	no information
2	Khudyaev 1931	J2 cl. J3 km-K1 nc	Povolgie Sysola Riv. Bas.	52°20'E, 59°35'N 49°30'-52°30'E, 60°00'-61°00'N	Rads from phosphate F° 49 sp , (with 20 n.sp.)	Marginal sea	Ammonites
3	Khabakov 1937	J3-K1 nc	Basin Vjatke Riv. Basin Kama Riv	50°00'-53°00'E, 56°00'-61°00'N	Rads from 2 horizons: Volgian and Neocomian 94 gen. & species	Upwelling zone	Ammonites
4	Lipman 1952	K2 st-cp	Kuznezk district of Penza region	47°00'-48°00'E, 53°20'-53°50'N	Descript. of 48 sp. with 37 n.sp.	Moderate water	Forams
5	Gorbachik & Druchziz 1959	K1 al	Crimea	34°15'E, 45°20'N	Presence of rads in clay	Shallow water	Forams
6	Aliev & Smirnova 1969	K1 al	Vladimir district	40°10'-41°30'E, 55°15'-56°30'N	Presence of rads in clay	Shallow water	Forams
7a	Kozlova 1971	J3 km	Pechora basin	57°E, 62°N	First quotation of rads list of 6 n.sp.	Shallow water	?
7b	Kozlova 1976	J3 V	??	??	numerous rads, 1 n.sp.	Shallow water	?
8	Gorbunov 1971	K1 al	Slavjansk	37°30'E, 49°00'N	badly preserv. rads from clay and sand	Shallow water	no data
9	Sichera & Semenov 1982	K2 st	Voronezh	38°00'-39°00'E, 51°30'-52°00'N	well preserved rads in sand	altern. shallow & moderate waters	no data
10	Bragina 1987	K2 st	Uljanovsk	48°00'E, 54°00'N	*id.*	*id.*	no data
11	Vishnevskaya 1987	K1 al-K2 cp	1-Moscow 2-Vladimir 3- Brjansk	37°00'-39°00'E, 55°00'-55°30'N 39°00'E, 56°00'N 35°E, 54°-55°N	Biozonation	Moderate water depth	1- *Inoceramus* 2- Forams 3- Forams in K1 al
12	Vishnevskaya & Kazinsova 1990	K1-2	Central Russian platform	30°-50°E, 40°-60°N	Comparison of rad. biozones	no info.	no info.
13	Vishnevskaya 1993	K1-K2	1-Moscow 2-Precaucasus	37°-39°E, 55°00-55°30'N 37°-40°E, 44°30'-45°30'N	Rads zonation + illustration	Moderate water-depth	Forams
14	Bragina 1994	K2 t-cp	Khotkovo of Moscow district	37°30'E, 55°30'N	Rads stratig.	?	*Inoceramus*
15	Kozlova 1994	J3 km	Pechora	57°30'E, 62°30'N	presence of rads	no info.	Macrofauna
16	Amon & De Wever 1994	K2	Povolgie	50°-60°E, 50-°60°N	Comparison of biozones	shallow water	Forams
17	Amon 1985	K2 t-cp	Usa river	57°-67°E, 66°-67°N	Rads biozone	shallow water	
18	Kazinsova & Olferiev in press	K1 al	Moscow region	37°-39°E. 55°N	Rads from "Paramonov" clay	shallow water	Forams

early Rhaetian are present also.

In New Zealand, radiolarians from Kapiti Island (Torlesse Terrane) studied by Blome, Moore, Simes & Watters (1987) are coeval with upper Norian faunas from the Monotis beds at Kunga Island. In the Waipapa Terrane, Aita (in Sporli & Aita 1988) figured a mixed fauna of Upper Triassic and Lower Jurassic Tethyan radiolarians from the red chert of Kawakawa Bay. Further references to this fauna and its use in solving complexities of terrane accretion in New Zealand are found in Sporli, Aita & Gibson (1989).

From Japanese cherts Yehara (1927) illustrated six rather nondescript circular forms from Shikoku. Other localities (Kimura 1944a, b) suspected to be Triassic yielded poorly preserved circular radiolarians, spongy forms with three arms, and closed cyrtoids. Since the late 1970's a number of radiolarian zonal schemes for the Upper Triassic have been proposed by workers in Japan. Amongst these Yao, Matsuda & Isozaki (1980) established three successive radiolarian assemblages of Middle Triassic to Early Jurassic age from continuous sequences of chert in the Inuyama area, central Japan. The lower assemblage is Middle Triassic; the middle one is Late Triassic, and the upper one is Early Jurassic. The Late Triassic assemblage was later separated into three sub-assemblages (Yao *et al.* 1980); the upper two of these were proposed for late Norian and Rhaetian forms, respectively. Numerous undescribed taxa were also figured at this time. In 1982, Kishida & Sugano established five assemblage zones for Triassic strata from the Chichibu Belt in the Kochi and Oita Prefectures, Japan. Kishida & Hisada (1986) renamed and subdivided some of their assemblages. Matsuoka figured upper Norian radiolarians from the southern subbelt of the Chichibu Belt, Kochi Prefecture (1983b) and discussed faunas from the Togano Group (1984b).

Subsequently Sato, Murata & Yoshida (1986) established the Betraccium deweveri Zone for upper Norian strata in the southern part of the Chichibu Terrane in Kyushu. Yoshida (1986) examined a Late Triassic to Early Jurassic bedded chert sequence in Kagamigahara City, Gifu Prefecture, central Japan, and subdivided it into seven radiolarian zones.

Also noteable are the works published by Ishida (1983), Kishida & Sugano (1982), Kojima (1982), Matsuda & Isozaki (1982), Nakaseko & Nishimura (1979a, b), Takashima & Koike (1982), Yao (1972, 1979, 1981, 1982a, b, 1983, 1986), Yao, Matsuoka & Nakatani (1982). In northern China, in initial studies of radiolarians from the Nadanhada Range, Kojima & Mizutani (1987) figured upper Norian and Rhaetian taxa from Triassic bedded chert. Subsequently, Kojima (1989) discussed the accretionary history of terranes along the continental margin of East Asia during Mesozoic time using Middle and Upper Triassic radiolarian assemblages (including some upper Norian and Rhaetian taxa) to point out similarities between the Nadanhada-Western Sikhote-Alin Terrane, and the Tamba-Mino-Ashio Terrane of southwest Japan. Implications are that the Nadanhada Range is the northern extension of the Japanese terrane. The history of this Mesozoic superterrane is further discussed by Mizutani, Shao & Zhang (1990) along with similar tectonostratigraphic terranes in the Ryukyu arc, the Philippines and probably Borneo. A more recent paper by Yang & Mizutani (1991) outlines the geology and biostratigraphy of the Nadanhada Terrane, presents preliminary revision of parasaturnalids, and describes new parasaturnalid taxa of latest Triassic and early Jurassic age.

In eastern Russia, Triassic faunas in the Sikhote-Alin Terrane, Sakhalin Island (Verchojan areas), and the Koryak Upland were studied by Bragin (1986, 1991a, b, 1994). Radiolarians and conodonts of mid Early Triassic to latest Triassic age (including late Norian and Rhaetian faunas) are present in chert sequences at Sikhote-Alin where seven radiolarian zones and seventeen conodont zones have been established. These forms are discussed and illustrated and new taxa are described. Goltman (1969) listed radiolarian genera occurring in the Triassic of Pamir, but until they are illustrated a comparison with other fauna is impossible. Among other publications from Asia one can also mentioned the works by: Bailey & Mc Callien (1953); Hudson *et al.* (1954); Ichikawa (1950); Kimura (1944a, b); Kobayashi & Kimura (1944b); Scrivenor (1929); Yehara (1927); Zhamoida (1958).

Europe (excluding the Russian platform)
Records of radiolarians are still relatively rare in Triassic sedimentary rocks if the variety of levels involved is considered. In fact, most of the information available to date has been obtained from Alpine faunas.
Triassic radiolarians have been recognised for a long time but comprehensive studies are quite recent. Indeed, following a preliminary note in 1887, Rüst recorded in 1892 about twenty species from twenty-eight Triassic samples of central European hornsteins and calcareous limestones. In the same year, Parona figured about a dozen poorly preserved forms including some with circular and elliptical outlines together with apparently spongy forms with three and four arms. Cyrtoids, of which some are multisegmented and conical and others with inflated middle and lower sections and apparently closed, tubular prolongations are also documented by Parona (1892). Wirz (1945) illustrated a few circular and chambered radiolatians in thin sections of dolomite from south of Lake Lugano (Italy). Most of these assemblages are not sufficiently well-described to permit comparison with faunas described in more recent papers. Following some other minor studies (Winkler-Hermaden 1934; Andrusov 1950), a renewal will come from several Austrian sequences of clays and limestones, Kozur & Mostler (1972) described some fifty well-preserved radiolarians belonging to the emended Coccodsicids, astracturids, heliodsicids, saturnalids and veghicyclids. In their study of Middle and Upper Triassic radiolarians, Kozur & Mostler (1981), Kozur (1984a, b) described a great number of new species and new genera from the Potschenkalk (Sevat) and Zlambach marls (Rhaetian) of Austria. Lahm (1984) figured Middle and Upper Triassic taxa from northern Italy and Austria; some of these ranging upward into the Sevat and Rhaetian. During rhe 1970's and 1980's there was a renewal of interest on these levels (from Greece, Sicily and Turkey: De Wever *et al.* 1979; De Wever 1982a, b; from Austria and Northern Italy: Donofrio & Mostler 1978; Kozur & Mostler 1978, 1979a, b, 1981, 1983, and subsequent work; from the Carpathians: Dumitrica 1977, 1978a, b; Dumitrica *et al.* (1980); from Yugoslavia: Gorican & Buser 1990; from northern Italy: Lahm, 1984 ...).
Samples yielding radiolarians are rare and localities wide-spread but, in Europe, mainly concentrated in the Tethyan realm: from Austria, Italy, Slovenia, Serbia, Montenegro, Albania, Greece and Turkey. Most of the Triassic bioevents have been inter-correlated and calibrated with Conodonts or Ammonites or Pelecypods. No well-preserved and comprehensively described Boreal or sub-Boreal faunas are known in sufficient number to be able to be considered as representative. Only recently some faunas have been recorded in Russia from northern Siberia (Egorov & Bragin 1995).

This synopsis illustrates that radiolarian workers around the world have shown a renewed interest in upper Norian and Rhaetian faunas since 1980, and that the tempo of research has accelerated quite rapidly in the past five years. Despite this intensity, the majority of the Rhaetian fauna remains undescribed.

JURASSIC
World (excluding Europe)
Pacific, Atlantic, Indian. None besides the paper from Colom (1954) in the Atlantic Ocean.
America. Following some preliminary work by Bonet & Trejo (1956), Riedel & Schlocker (1956) and Smith (1916), the first substantial papers dealing with Early Jurassic radiolarians from Northern America were published by Pessagno and his collaborators (Pessagno & Blome 1980, 1982; Pessagno & Whalen 1982) and more recently by Yeh (1987). In the Caribbean apparently only one questionable paper by Vermunt (1937) can be quoted. Mattson & Pessagno (1979) reported Late Jurassic and Early Cretaceous radiolarians in Puerto Rican cherts and limestones. Pessagno (1977b) was able to erect a radiolarian zonation for the Late Jurassic, on the basis of forms occurring in cherts and limestone nodules in California.
SE Asia (Japan, Indonesia, Far East Russia). In the circum-Pacific region, Hinde (1917) listed poorly preserved Late Jurassic radiolarians in cherts from several localities in the Celebes.

Some general quotations of Jurassic radiolarians in SE Asia may be found in Bailey & Mc Callien (1953), Hudson *et al.* (1954), Huzimoro (1938), Kawada (1953), Khabakov (1932, 1937), Khudyoev (1931), Kimura (1944a), Kobayashi (1935), Tromp (1947, 1948), Yehara (1927), Zhamoida (1972), and from Indonesia in Brouwer (1921), Hinde (1917), Krumbeck (1922) and Vogler (1941). Coomaraswanny (1902) recorded the presence of Jurassic radiolarians together with plant remains in India. A broad summary of Late Jurassic and Cretaceous radiolarians, with a definition of seven distinct assemblages, was provided by Nakaseko & Nishimura in 1981. Since then recent workers are elucidating Japanese occurrences such as Aita (1982), Mizutani (1981), Matsuoka (1982a, 1983a) and numerous other workers.

Europe (excluding the Russian Platform)

The pioneer work on Late Jurassic radiolarians was based on Italian and Swiss localities. Rüst (1885) provided the original descriptions of assemblages from jaspers, flints and siliceous shales from a number of localities in the Allgau (southern Germany) and Austria (Urschlau) and from redeposited pebbles in western Switzerland. He also obtained rich assemblages from coprolites from iron mines at Ilsede, further north in Germany (near Hannover). This important paper presented seventy-two species dated as Late Lias-Early Dogger by associated ammonites. Rüst (1885) also recorded radiolarians in the Tithonian (Aptychus beds) from the Alps, in the flysch of Teisendorf (in the Achatal), in the flysch from Traustein (Upper Bavaria) and also from Neocomian levels of the Carpathians near Podbiel. Wisniowski (1889) described moderately preserved forms in siliceous concretions from the vicinity of Krakow, Poland.

Italian authors described diverse assemblages from flint nodules in limestones at Cittiglio (Parona 1890), and radiolarite and siliceous shales at Spezia (Vinassa 1898a, b, 1899), Monginevro (Squinabol 1913) and the Bolognese (Neviani 1900). Cayeux (1896) reported calcitized radiolarian skeletons in Tithonian limestones in the region of the Ardeche in southern France. Cayeux (1897) mentioned poorly preserved Jurassic radiolarians (Sch. inflata ammonite Zone) in the "Gaize" from Argonne, from Cher (France).

Muzavor (1977) described well-preserved radiolarians from siliceous marl at Oberaudorf (Bavaria). Steiger (1981) illustrated well-preserved forms from limestone turbidities in the vicinity of Salzburg. From broadly based studies of Tethyan assemblages the first radiolarian biozonations for Europe were made by Baumgartner *et al.* (1980) and Kocher (1981).

Radiolarian biostratigraphic schemes for Jurassic and Cretaceous sequences were proposed by Tikhomirova (1984, 1987) and Kazinsova (1984) for the Carpathians and the Lesser Caucasus, but, as these investigations are based on thin sections they are out-of-date and probably inaccurate.

Other early papers dealt with Jurassic levels from Western Europe (Andrusov 1950; Anonymous 1959; Bergounioux 1950; Cayeux 1891, 1896; Downie 1956; Cita 1965; Dacqué 1933; Deflandre 1953; de Lapparent 1925; Dunikowski 1882; Furrer 1951; Geyer 1961; Heitzet 1930b; Jacob & Nicorici 1957; Innocenti 1927; Jaccard 1909; Jodot 1931; Kraus 1914; Leischner 1961; Pantanelli 1880, 1887-1889; Parona 1892; Protescu 1933; Rüst 1885, 1898; Sido & Sikabonyi 1953; Termier & Maury 1928; Trauth 1950; Vadasz 1952; Vinassa 1898a, b, 1899; Weynschenk 1950, 1951; Winkler-Hermaden 1934). Data for Jurassic radiolarians are numerous in folded Tethyan terranes and radiolarians are the main constituents of the rocks for numerous Late Jurassic localities (in all the radiolarite type facies). A large number of papers have been published during the last two decades including: Baumgartner 1980; De Wever 1982a, b; De Wever *et al.* 1986b; Dumitrica 1970; Gorican 1994, ...

The first biostratigraphically significant papers dealing with Early Jurassic radiolarians were published recently from Tethyan realm (Pessagno & Poisson 1981; De Wever 1981a, b, 1982a; De Wever & Origlia-Devos 1982; Gorican 1994).

An available set of stratigraphic markers can be based on some recent work (Gorican 1987, 1994) and on the synthesis published by the InterRad group (1995). In spite of the abun-

dance of work published during the two last decades, most of them deal with the Tethyan realm and almost no significant publications relate to the true Boreal realm. No well preserved Boreal or sub-Boreal faunas are described in the literature and only some radiolarian species are mentioned in very sparse localities [Scotland: Dyer & Copestake 1989 and Russia: Khabakov 1937 (illustration of the latter is too poor to be useful), and more recently Bragin (1994) and Bragin & Bragina (1995)]. Therefore, at present, there is no reliable general datum available to use for the Boreal province.

No warm *vs* cold faunas have been identified with confidence to date in western Europe. This is mainly due to the fact that much of the currently available information has been gathered from radiolarite-type facies and that this type of sedimentary rock was deposited under the most active parts of upwelling systems (see above De Wever *et al.* 1994).

CRETACEOUS

World (excluding Europe)

Some general reports (by topic or by location) were published by Krasnyi *et al.* (1962), Rüst (1887), Socco (1905) and, in Africa, by Magné & Sigal (1953).

Pacific, Atlantic, Indian. Several studies based on DSDP material have contributed to the taxonomic and stratigraphic understanding of Early Cretaceous radiolarians (Moore 1973; Riedel & Sanfilippo 1974; Foreman 1975). DSDP sequences from the North and Central Pacific have contributed very substantially to Middle and Late Cretaceous stratigraphic zonation (Foreman 1971, 1975; Schaaf 1981) and for a predominantly taxonomic study by Empson-Morin (1981). Late Cretaceous radiolarian stratigraphy in the Eastern Atlantic has been aided by the Deep Sea Drilling Project (Petrushevskaya & Kozlova 1972; Foreman 1978b). DSDP sequences drilled in the eastern Atlantic provided information on radiolarian stratigraphy in that region (Foreman 1978b; Basov *et al.* 1979, for the Early Cretaceous). Foreman (1977) summarised occurrences in the Atlantic Ocean and its borderlands, and refined the Late Cretaceous zonation of that region.

DSDP cores from the eastern Indian Ocean provided the basis for the description of three stratigraphically significant assemblages in the Middle and Late Cretaceous (Renz 1974). Moderately preserved Late Cretaceous radiolarians are recorded in Indian Late Cretaceous phosphatic nodules by Garg & Jain (in press).

America. Among some of the earliest works conducted in North America one can cite: Bolin 1956; Campbell & Clark 1944; Crandell 1952; Eicher 1960; Foreman 1966; Göke 1959; Hinde 1894; Nauss 1947; Payne 1962; Ransome 1894; Riedel & Schlocker 1956; Rubey 1929; Rüst 1892, 1898; Searight 1938; Tyrrell 1890; Woodward & Thomas 1885, 1895; and for South America: Galavis 1951; Richter 1925; Stainforth 1948; Thalman 1946; and for Caribbean: Ayala-Castanares 1959; Brönnimann & Rigassi 1963; Foreman 1966; Palmer 1934; Pessagno 1960, 1962, 1963; Vermunt 1937. The circum-Pacific region is represented by descriptions of radiolarian assemblages from the Cenomanian of California (Pessagno 1971a) and of Costa Rica (Schmidt-Effing 1980).

Radiolarians are recorded in Campanian limestones of Puerto Rico (Pessagno 1963), and as pyritized skeletons in the Late Cretaceous of Venezuela (Galavis 1951). Also, in the Caribbean region, the Deep Sea Drilling Project has provided data on Late Cretaceous radiolarian stratigraphy (Sanfilippo & Riedel 1976). Mid-Cretaceous radiolarians were reported by Basarovski (1991) from Central America (Cuba).

For North America, the earliest record of Cretaceous radiolarians is from the Pierre shale of Manitoba, by Rüst (1892, 1898). Occurrences of Albian and Campanian radiolarians in Alberta were recorded by Wall (1975). Campbell & Clark (1944) described a diverse Campanian assemblage from California, and a sparse Franciscan assemblage was recorded by Riedel & Schlocker (1956). Californian assemblages were exploited to greater stratigraphic advantage by Foreman (1968) and Pessagno (1970, 1971a, 1972, 1973 and 1976). The paper last cited established eight Late Cretaceous radiolarian zones in California, and described a substantial number of new taxa. Pessagno (1977b) proposed a Berriasian to Albian zonation and a large number of new taxa on the

basis of assemblages from calcareous nodules from a number of Californian localities.

E Asia (Japan, Indonesia, Far East Russia). The first investigation of Early Cretaceous radiolarians in the circum-Pacific belt was conducted by Hinde (1900), who investigated them in numerous samples of cherts, marls and limestones from Central Borneo. From the Cretaceous chalks on the Indonesian island of Rotti, Tan Sin Hok (1927) described a diverse, well-preserved assemblage that is now believed to be between Albian and Turonian in age (Riedel & Sanfilippo 1974). Nakaseko *et al.* (1979b) distinguished a number of stratigraphically significant assemblages through the Cretaceous and Palaeogene of Japan, and compared them with zonal schemes developed for deep-sea sequences. A more recent compilation of the stratigraphy of Japanese Middle and Late Cretaceous radiolarians, defining zones and a number of new taxa, was produced by Taketani (1982).

Descriptions of radiolarian assemblages from the Cenomanian of Sakhalin include Kazintsova (1981). Among others, the following works were published: Alicv 1961a, b, 1965; Dundo & Zhamoida 1963; Hudson *et al.* 1954; Karitskii 1889; Khabakov 1932, 1937; Khudyaev 1931; Kozlova & Gorbovets 1966; Lipman 1952, 1960; Mittermaier 1896; Nakaseko *et al.* 1965; Rao 1932; Vassoevich 1938. From Australia and New Zealand publications include: Crespin 1946, 1960; Dun *et al.* 1901; Etheridge & Dun 1902; Hinde 1893; Foreman 1966. From Indonesia: Brouwer 1921; Foreman 1966; Tan 1927; Vogler 1941. Berriasian blocks in a Turonian chert matrix yield well-preserved radiolarians from Tibet (Wu & Li 1982), and Dundo & Zhamoida (1963) investigated Valanginian radiolarians in siliceous volcanogenic rocks from the Far-Eastern USSR.

Nakagawa & Nakaseko (1977) listed and illustrated radiolarians from a Jurassic and an Early Cretaceous locality in Japan. A Late Cretaceous radiolarian occurrence in manganese carbonate ore in Japan is described by Yao (1979).

Europe (excluding the Russian platform)

As is the case for the Jurassic, most of the initial research on Early Cretaceous radiolarians was based on European material but today current investigations are more widely dispersed.

Coprolites and siliceous limestones from Zilli (Saxony) and Gardenazza (northern Italy) provided most of the Early Cretaceous forms described by Rüst in his paper of 1888, and ten years later he added forms from the cherty limestones of Cittiglio in northern Italy (Rüst 1898; see also Parona 1890). Fischli (1916) illustrated a diverse faunal assemblage from flints in a Swiss conglomerate. Sollas (1873) mentioned radiolarians in coprolites from the Cambridge Greensand and, 30 m below, in the Gault Clay from Bedfordshire (UK). *Quaterly Journal of the Geological Society* (p. 78)) and Grimes (1895: 345) described two species from the Lower Greensand of Surrey (UK). In 1883, Wallich recorded the presence of four genera of radiolarians in the cavities of hollow cherts from Surrey (UK). Fritsch (1893) recorded the presence of eleven species in marly beds of Prisen (Senonian) from Bohemia, and Deecke (1894) some radiolarians in chalks flints at Rügen. Hill & Jukes-Browne (1895) mentioned the presence of radiolarians in chalks of the Melbourne Rock (UK). Cayeux (1897) mentioned twenty-seven genera and described numerous species of Turonian radiolarians from SE, N and NW of the Paris Basin (France) and from smectite du Hevre (Belgium). Holmes (1900) recorded twenty genera and forty-one species from the chalk in Surrey (UK). Zittel (1876) described the first Cretaceous radiolarians from northern Germany, in spite of a poorly preserved fauna. Tethyan radiolarian assemblages of Middle Cretaceous age have been described by Squinabol (1914) from the Veneto region of Italy. Ravn G. (before 1911) mentioned the presence of Upper Cretaceous radiolarians in Arnager limestones (Island of Bornholm, Denmark).

Over the decades, Cretaceous radiolarians have been described from scattered localities (Andrusov 1950; Anonymous 1959; Colom 1954; Corti 1896, Custodis & Schmidt-Thomé 1939; Deecke 1895; Elbert 1902; Fric 1893; Furrer 1951; Grimes 1895; Heitzer 1930; Hill 1912; Hill & Jukes-Brown 1895; Holmes 1900; Jodot 1931; Lombard & Schröder 1939; Neviani 1900, 1901; Pantanelli 1880, 1887, 1889;

Parona 1890; Perner 1891; Protescu 1933; Rüst 1887, Squinabol 1903, 1904, 1914; Sujkowski 1931; Vasicek 1947; Vinassa 1901; Vinassa 1900; Wallich 1883; Wetzel 1933, 1961). In the 1960's evidence accumulated for an abrupt evolutionary change at or near the Cretaceous/Palaeocene boundary (Lipman 1952; Foreman 1968), and consequently, large numbers of new Cretaceous genera and several new families have been described (*e.g.* by Cita 1965; Foreman 1966, 1968; Dumitrica 1970; Herm 1962; Empson-Morin 1981).

Baumgartner *et al.* (1980) proposed a preliminary stratigraphy based on a number of widely scattered radiolarian assemblages from the Tethyan region. Boyanov & Lipman (1973) were able to use a poorly preserved radiolarian assemblage to determine the Early Cretaceous age of Bulgarian siliceous shales previously considered to be Palaeozoic, and Lozynyak (1969) recorded assemblages of this age from the Ukrainian Carpathians. In the Kuznetsk area of the Russian Platform, Lipman (1952) recorded numerous radiolarian taxa in samples from drilled wells. Goltman (1971, 1975) recorded occurrences in limestones and marls of the Tadjiksk Depression, culminating in a useful stratigraphic compilation (Goltman 1981). Lipman (1960) described numerous assemblages of Coniacian to Danian age in wells and surface exposures of the Western Siberian Lowland, and Kozlova & Gorbovets (1966) described characteristic complexes for the Turonian to Campanian deposits of that region.

Tethyan radiolarian assemblages of Middle Cretaceous age have been described by Kozlova in Basov *et al.* (1979) from a DSDP Site off Spain, and by Dumitrica (1970, 1975) from Romanian marls and radiolarite.

In spite of the abundance of work published during the two last decades, most of them deal with the Tethyan realm and almost no significant papers consider the true Boreal realm. No well preserved Boreal or sub-Boreal faunas are described in the literature. Some species are only recorded rarely from very isolated localities and therefore there is no available datum to use in confidence for the Boreal province and we have chosen to omit such datums from the Cretaceous chart. Biostratigraphic data exists in a series of papers among which the most significant are Jud (1994) for the zones in Early Cretaceous, Erbacher (1994) and O'Dogherty (1994) for the middle part of Cretaceous, Sanfilippo & Riedel (1985) and Khoklova *et al.* (1994) for the Late Cretaceous together with Urquhart (1994) and Bragin (1995) for the Late Cretaceous of Cyprus. By the Late Cretaceous, the Tethyan environment for the accumulation of radiolarian sediments had practically disappeated, and a Palaeogene pattern was developing. The only substantial occurrences in the Mediterranean region are in the north Italian *Euganei* (Squinabol 1903, 1904), and in Greece (De Wever & Thiébault 1981). There are significant records in Senonian and Turonian shales of Czechoslovakia (Perner 1891), in Campanian chalks of northern Germany (Zittel 1876) and in France and Belgian Campanian silicified limestones (Cayeux 1897).

Danian-Palaeocene

Publications dealing with this time period are not numerous. Literature recording occurrences from Asia includes the following work: Hollis 1991; Vishnevskaya 1981-1988c; Basov & Vishnevskaya 1995; from the Atlantic realm: Saito *et al.* 1966; from the East Indies: Reinhard & Wenk 1951; from Europe: Anonymous 1959; Stoesche & Hiltermann 1940; Twerenbold 1955; Borisenko 1958, 1960, Kozlova 1993 and from North America: Frizzell & Middour 1951.

RADIOLARIAN STUDIES FROM THE RUSSIAN EUROPEAN PLATFORM

Khudjaev I. E. (1931) in a paper entitled "On the Radiolaria in the phosphates in the region of the Syssola River" described forty-nine species, belonging to ten genera, where twenty-eight species were determined as new. They are *Cenosphaera komiensis* n.sp., *C. syssolae* n.sp., *C.* sp. indet. N1, *C.* sp. indet. N2, *Carposphaera affinioides* n.sp., *Lithapium supraspinosum* n.sp., *Lithocyclia ovalis* n.sp., *Porodiscus* sp. indet. N1, *P.* sp. indet. N2, *Cornutanna ovalis* n.sp., *Dicolocapsa trapezoidalis* n.sp., *D.* sp. indet. N1, *D.* sp. indet. N2, *Tricolocapsa multipora* n.sp.,

Phormocampe favosa n.sp., *Dictyomitra multipora* n.sp., *D. spicularia* n.sp., *D. biporosa* n.sp., *Lithocampe syssolaensis* n.sp., *L.* sp. indet. N1, *L.* sp. indet. N2, *Cyrtocapsa rusti* n.sp., *Stichocapsa chabakovi* n.sp., *S. regularis* n.sp., *S. quadripora* n.sp., *S. kassini* n.sp., *S. zyrjanica* n.sp. and *S. wisingiana* n.sp.

Khabakov (1937) in his paper "Radiolarians from Lower Cretaceous and Upper Jurassic phosphorites of Vjatka and Kama River Basins" described nineteen genera and seventy-five species of radiolarians.

Lipman (1952) in her monograph "Materials on monographic study of Upper Cretaceous radiolarians from the Russian platform" described forty-eight radiolarian species, where thirty-eight were described as new species. They are: *Cenosphaera minor* n.sp., *C. mammilata* n.sp., *Cenellipsis elliptica* n.sp., *Xiphosphaera irregularis* n.sp., *Cromyodruppa concentrica* n.sp., *Cenodiscus lens* n.sp., *Spongoprunum crassum* n.sp., *S. angustum* n.sp., *S. articulatum* n.sp., *Trochodiscus spiniger* n.sp., *Triacticus triacuminatus* n.sp., *Porodiscus vulgaris* n.sp., *Stilodictya delicatula* n.sp., *S. placentalis* n.sp., *Tripodictya triacuminata* n.sp., *Euchitonia santonica* n.sp., *Hagiastrum crux* n.sp.,

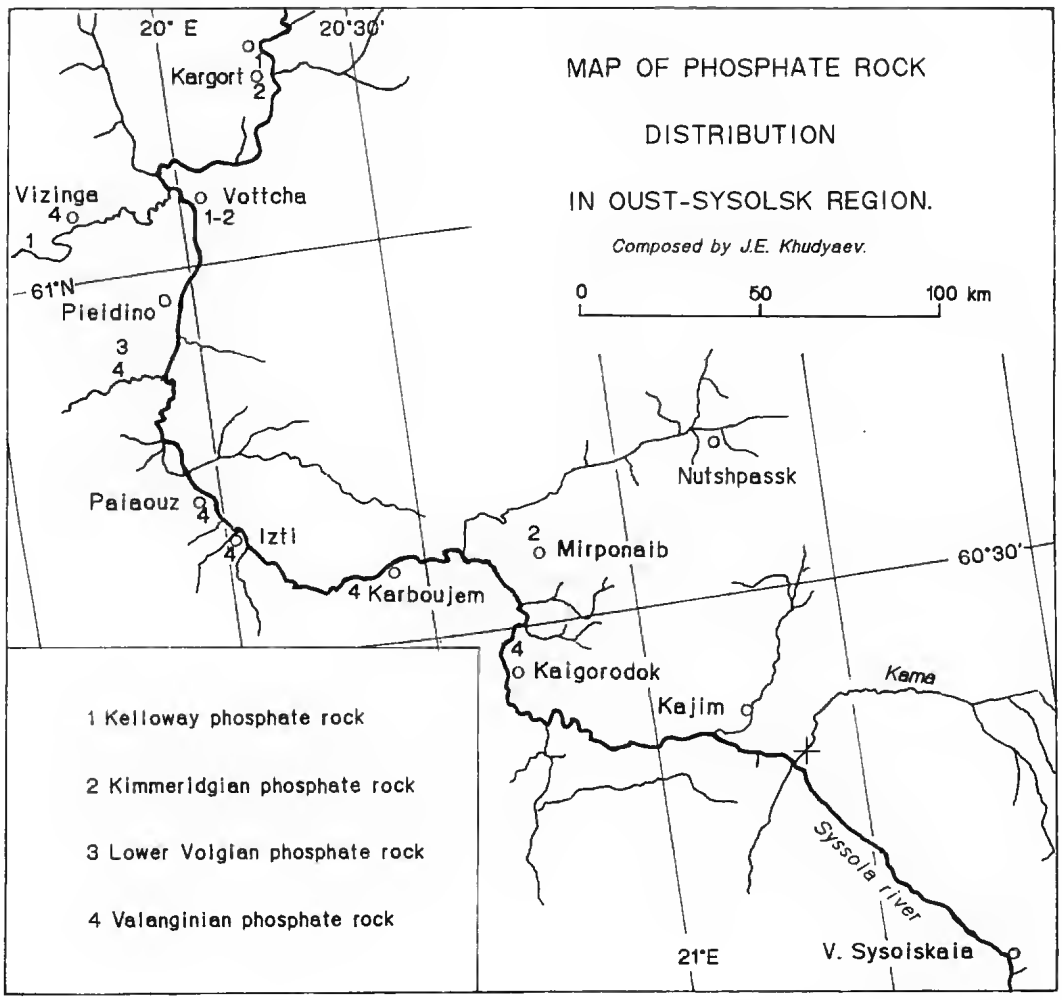

FIG. 2. — Location map of sites reported by Khudyaev (1931) in published investigations of Oust-Sysolk region (20°-21°E, 30°N).

Histiastrum cruciferum n.sp., *H. aster* n.sp., *H. membraniferum* n.sp., *H. irregulare* n.sp., *Tesserastrum quadratum* n.sp., *Rhopalastrum trigonale* n.sp., *R. tumidum* n.sp., *R. ingens* n.sp., *R. attenuatum* n.sp., *Spongodiscus impressus* n.sp., *Spongodiscus citrus* n.sp., *S. maximus* n.sp., *S. volgensis* n.sp., *Spongotripus aculeatus* n.sp., *Stylotrochus hexacanthus* n.sp., *S. dolichacanthus* n.sp., *S. actacanthus* n.sp., *Lithostrobus turritella* n.sp., *Dictyomitra scalaris* n.sp., *D. gigantea* n.sp., *D. striata* n.sp. All species derived from Santonian-Campanian clay of Penza region.

Aliev & Smirnova (1969) in their paper "New species of radiolarians from Albian of Central areas of the Russian platform" described from Upper Albian (40 m thick) clay, with Albian foraminiferas of the Vladimir district, six new species: *Porodiscus kavilkinensis* Aliev n.sp., *P. inflatus* Smirnova *et* Aliev n.sp., *Sethocyrtis mosquensis* Smirnova *et* Aliev n.sp., *Theocampe cylindrica* Smirnova *et* Aliev n.sp., *T. simplex* Smirnova *et* Aliev n.sp., *Stichocampe cuneatus* Smirnova *et* Aliev n.sp. and one subspecies *Dictyomitra ferosia* Aliev subsp. *angusta* Smirnova

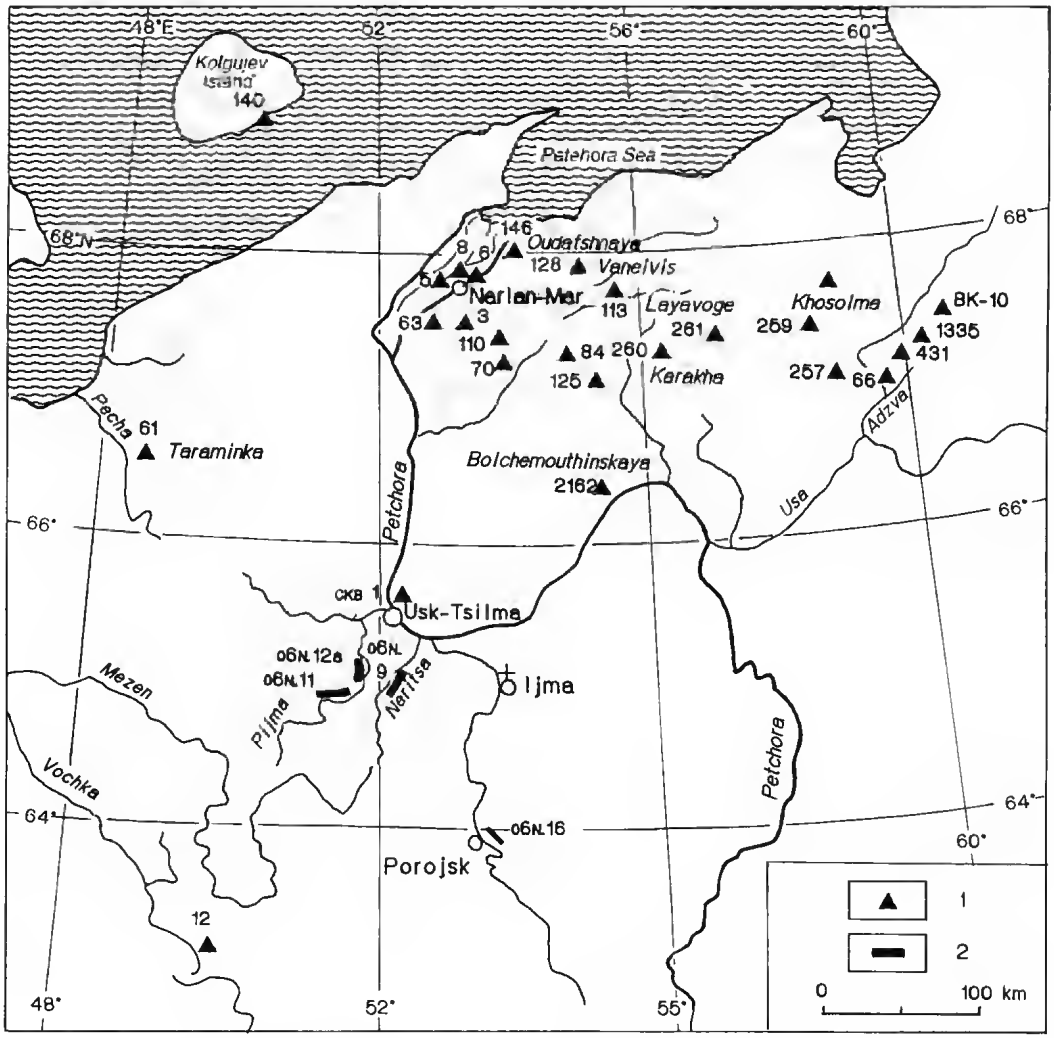

FIG. 3. — Location map of sites (drill holes -1- and outcrops -2-) reported by Kozlova (1994) in published investigations of Pechora (48°-60°E, 64°-69°N).

sub.n.sp. A number of forms from the Ukrainian Carpathians are described by Lozynyak (1969, 1975), and other forms from Azerbaidzhan are described in a series of papers by Aliev (1961a, b, 1965, 1969a, b) on Valanginian, Aptian, Albian and Cenomanian assemblages in which many of the radiolarians are calcitized.

Kozlova (1971) in her paper "About finding of radiolarians in the lower Kimmeridgian strata of the Timan-Urals region" reported the radiolarian assemblage from white marl strata of 10 cm thick with the ammonites *Amoeboceras kitchini* Salf, *Rasenia* cf. *trimera* Opp. The assemblage included seventeen species, where five species were new: *Stylosphaera ? asperalla* Kozlova n.sp., *Staurodictya retusa* Kozlova n.sp., *Hagiastrum crassum* Kozlova n.sp., *H. squama* Kozlova n.sp., *Spirema ? sphaerica* Kozlova n.sp. She emphasized that these newly discovered assemblages are similar to the Lower Cretaceous assemblages from Vjatka and Kama River Basins, previously described (Khudjaev 1931; Khabakov 1937).

A paper by Kozlova (1973) "New species from lower Kimmeridgian of the Timan-Urals region" gave the description of all new species listed in her previous paper (Kozlova 1971). Poorly-preserved Albian radiolarians from the Dnieper-Don Basin were reported by Gorbunov (1979).

Kozlova (1983) in her paper "Late Volgian radiolarians of USSR North" recognized three radiolarian assemblages: lower Kimmeridgian *Crucella crassa*, Volgian *Stichopilidium planocephala*, Berriasian *Hemicryptocapsa salymica* and described *S. planocephala* n.sp.

Kozlova (1994) in a paper entitled "Assemblages of Mesozoic radiolarians from the Timan-Pechora oil-bearing region" describes precise characteristics of four radiolarian assemblages: lower Kimmeridgian *Crucella crassa*, middle Volgian *Parvicingula papulata*, upper Volgian *Pseudocrolanium planocephala* and upper Berriasian-lower Valanginian *Hemicryptocapsa salymica*, which were partly described in her previous papers (Kozlova 1973, 1976). About twelve species were illustrated as new in this paper. Vishnevskaya (1993) in a paper "Jurassic and Cretaceous radiolarian biostratigraphy in the USSR" illustrated twelve species from Coniacian-Santonian strata from the Moscow district.

Bragina (1994) in her paper "Upper Cretaceous radiolarians and stratigraphy of Khotkovo Group, Moscow region" studied radiolarians in four sections and proposed two biostratigraphic units: Coniacian (?) - Campanian (*Archaeospongo-prunum bipartitum-Crucella irwini*) and Campanian (*Archaeospongoprunum hueyi-A. salumi*). She counted more than 50% of Californian species among these Russian plate assemblages.

Vishnevskaya (1996) in a paper "Peri-Tethyan radiolarians and their implications" illustrated eighteen species from Albian-Santonian of the Moscow, Kaluga and Brjansk areas.

CONCLUSION

The improvement of a taxonomic system for Mesozoic radiolarians is hampered by a general lack of well-preserved specimens from well organised sequences which are needed to develop the basis for a reliable hypothesis of evolutionary links. This has represented an important factor in the approach chosen by some authors (*e.g.* Pessagno 1969a, b, 1971a, 1977b; Empson-Morin 1981, 1982; Kozur & Mostler 1972-1989) who produced a highly-split taxonomic hierarchy indicating all observed morphological characters. A highly-divided taxonomy is useful for the recognition of slight morphological variations which may eventually be comprehended as expression of paleoenvironmental conditions. This does not necessarily, however, advance the general aim of a taxonomy which considers phyletic relationships, and it often results in species which are too narrowly delimited to be broadly suitable for stratigraphic purposes. However, correlations are a primary phase in the move towards settling the succession of species on which a natural classification can be based. Fulfilment of these aims would allow a better appreciation of the paleobiodiversity of these organisms and provide a useful tool for measuring geological time.

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TABLE 2. — Publications on Mesozoic radiolarians, with indications of the localities, involved ages and main topic (except publications dealing with European part of the former Soviet Union, see table 1).

LOCATION	AGE	TOPIC	AUTHOR
	Czc Mzc	Evolu.	Kellogg D. E. 1982
	Pzc Mzc	Gener. Strati Evolu.	Kling S. A. 1978
	Mzc Czc	Taxon. DSDP14	Petrushevskaya M. G. & Kozlova G. E. 1972
	Mzc	Taxon. Skelet.	Nakaseko K. & Yao A. 1973
	Czc Mzc?		Levykina I. E. 1984
	Czc Mzc Pzc	Taxon. Gener.	Moore R. C. 1954
	E.Cret.-L.Jur.		Khabakov A. V. 1937
	Cret.	Taxon. N.Sp.	Foreman H. P. 1966
	Mzc	Skelet.	Deflandre G 1964
	Tr.	Taxon. N.Sp. Evolu.	Dumitrica P. 1978a
	Mzc Czc	General	Deflandre G 1953
	Mzc	General Skelet. Morphogen.	Deflandre G. 1960
	Czc Mzc	Skelet. Growth Morphogen.	Deflandre G. & Deflandre-Rigaud M. 1958
	Mzc	Taxon. N.Sp.	Kozur H. 1979
	PCzc? Mzc?	Plankton	Meyen F. J. 1896
	Mzc Czc	Taxon. Evolu. Skelet.	Petrushevskaya M. G. 1981
	Mzc Czc	Taxon. Skelet.	Petrushevskaya M. G. 1986
	Mzc	DSDP26	Pessagno E. A. Jr & Michael F. Y. 1974
	Pzc-Czc	General Taxon. Biol. Strati	Goll R. M. & Merinfeld E. G. 1979
	Czc Mzc Pzc	Sedim. Review of papers	Hill W. 1912
	Mzc Czc	Taxon. Skelet.	Petrushevskaya M. G. *et al.* 1976
		Taxon. Skelet.	Petrushevskaya M. G. 1979
	Czc	Taxon. Skelet.	Petrushevskaya M. G. 1975b
	Czc Mzc	Skeleton Ontogen. Shape	Nishimura H. 1986
	Mzc Pzc	Taxon. Skelet.	Petrushevskaya M. G. 1975a
	L.Cret.	DSDP29	Pessagno E. A. Jr 1975
	Mzc Czc	Taxon.	Petrushevskaya M. G. 1975c
	Jur.Czc.	Taxon.	Dumitrica P. 1988
	Late Cret.	Taxon. Evolu.	Empson-Morin K. M. 1982
	Cret.	Taxon. Strati	Sanfilippo A. & Riedel W. R. 1985
	M.Cret. Recent	Skelet.	Thurow J. & Anderson R. O. 1986
	Jur.	Taxon. Skelet.	Takemura A. 1986
	Mzc Czc	Taxon.	Riedel W.R. 1967a
	Czc	Taxon.	Riedel W. R. 1967b
	Mzc	Strati Taxon.	Tshedia D. M. 1985
	Cret.	DSDP7	Foreman H. P. 1971
	Mzc Cret.	Strati Taxon. DSDP20	Foreman H. P. 1973b
	Cret. Czc	Taxon. Evolu.	Dumitrica P. 1985
	Pzc-Czc	Taxon.	Dumitrica P. 1984
		Technic. SEM Taxon.	De Wever P. 1980
	Mzc	Evolu. Biol.	Doderline L. 1887
	Pzc-Czc	Gener. Taxon.	Dumitrica P. 1979
	Pzc Mzc	General Taxon.	Foreman H. P. & Riedel W. R. 1972
	Cret.-Czc	Taxon. Strati DSDP10	Foreman H. P. 1973a
		Taxon.	Cordey F. *et al.* 1988
	Czc Mzc?	DSDP1	Ewing M. *et al.* 1969
	Mzc Czc	Taxon. Gener.	Deflandre-Rigaud M. 1969
Africa Algeria	Cret. Alb.-Cenom.		Magné J. & Sigal J. 1953
Amer. N.England, Austral. California	Pzc Mzc		Blake M. C. Jr & Murchey B.L. 1988

LOCATION	AGE	TOPIC	AUTHOR
Amer.C.	Mzc	Taxon. DSDP	Pessagno E. A. Jr & Longoria T. J. F. 1973
Amer.C.	Earl.Cret. Mzc		Alcocer V. M. D. 1960
Amer.C. Calif. Mexico (B. California)	L.Tr.	Strati Taxon.	Pessagno E. A. Jr *et al.* 1979
Amer.C. Carib. Bahama	Mzc	DSDP1	Pessagno E. A. Jr 1969
Amer.C. Carib. Cuba	Mzc		Vishnevskaya V. S. *et al.* 1982
Amer.C. Carib. Venezuela	Jur.-Cret.	Strati Ophiol.	Beck C. *et al* 1984
Amer.C. C. Rica, Tethys, Greece, Italy	L.Jur.-Earl.Cret	DSDP	Devos I. 1983
Amer.C. Costa Rica Indian	Jur.-Cret.	DSDP Taxon. Strati	Origlia-Devos I. 1983
Tethys Greece Italy (Sicily)			
Amer.C Costa Rica,	Earl.-Mid.Jur.	Strati Taxon.	De Wever P. *et al.* 1985a
Amer.C. Costa Rica		Strati Ophiol.	Bourgois J. *et al* 1982
Amer.C. Costa Rica			Wildberg H. *et al.* 1982
Amer.C. Costa Rica Nicoya		Strati Ophiol. Radt	Schmidt-Effing R. 1980
Amer.C. Costa Rica Nicoya	Jur.-Cret.	Strati Ophiol.	Schmidt-Effing R. 1979
Amer.C. Costa Rica Nicoya	Cret.	Strati	Schmidt-Effing R. *et al.* 1980
Amer.C. Costa Rica Nicoya	Cret.	Strati Radt	Schmidt-Effing R. 1980
Amer.C. Costa Rica, Nicoya		Radt Ophiol. Sedim.	Gursky H.-J. & Schmidt-Effing R. 1983
Amer.C. Costa Rica Nicoya	Jur-Cret.	Radt Ophiol.	Steinberg E. 1988
Amer.C. Costa Rica Nicoya	M.-Cret.	Strati	Schmidt-Effing R. 1980
Amer.C. Costa Rica Nicoya	Mzc	Ophiol.	Gursky H.-J. 1988
Amer.C. Costa Rica NW. Nicoya,	Jur.-Cret.	Strati Sedim.	Gursky H.-J *et al.* 1982
Amer.C. Cuba.	Campan.	Strati	Florez Albin E. 1988
Amer.C. E.Mexico.	Tithonian	Taxon.	Yang Q. & Pessagno E. A. 1989
Amer.C. Puerto Rico	Jur.-E.Cret.	Taxon. Strati	Mattson P. H. & Pessagno E. A. Jr 1979
Amer.C. Tethys	Jur.-Cret.	Radt	De Wever P. *et al.* 1986a
Amer.C. W.Atlant. Blake Bahama	M.Jur.		Yamamoto H. *et al.* 1985
Amer.N.	Jur.	Taxon.	Pessagno E. A. Jr *et al.* 1989
Amer.N.	Tr.	Biozon. Taxon. Strati	Blome C. D. 1984b
Amer.N.	Jur.	Strati Zones	Pessagno E. A. Jr *et al.* 1987
Amer.N.	Mzc	Taxon. Strati Gener.	Campbell A. S. & Moore R. C. 1954
Amer.N. Alaska	Tr.	Biostr.	Blome C. D. *et al.* 1989
Amer.N. Alaska. USA	Earl.Mzc	Paleogeog. Envir.	Blome C. D. 1987
Amer.N. Calif. Franciscan	Jur.-Cret.	Strati	Davis E. F. 1918
Amer.N. Calif. ex-USSR Asia Japan	Mzc	Bioz.	Vishnevskaya V. S. 1985
Tethys Europe			
Amer.N. Calif.	Jur.-Cret.	Taxon.	Pessagno E. A. Jr 1973
Amer.N. Calif.	Cret.	Taxon. Strati	Foreman H. P. 1968
	L.Maastrichtian		
Amer.N. Calif.	L.Jur.	Ophiol.	McLaughlin R. J. & Pessagno E. A. Jr 1978
Amer.N. Calif.	Czc Mzc?	Sedim.	Hinde G. J 1894
Amer.N. Calif.	Tr.-Cret.	Taxon.	Pessagno E. A. Jr 1977c
Amer.N. Calit.	L.Cret.	Taxon.	Pessagno E. A. Jr 1971a
Amer.N. Calif.	Jur.-Cret.	Taxon.	Pessagno E. A. Jr 1971b
Carib. Bla.-Bahama Gr.Valley			
Amer.N. Calif. Coast Ranges	L.Jur.-Cret.	Strati Taxon.	Pessagno E. A. Jr 1977a
Amer.N. Calif. Franciscan		Taxon.	Riedel W. R. & Schlocker J. 1956
Amer.N. Calit. Franciscan Gr.Valley			Seiders V. M. *et al.* 1979
Amer.N. Calit. Fransciscan	Jur.	Radt Ophiol. Strati Lithol.	Murchey B. 1984
Amer.N. Calit. Gr.Valley-Blake-Bahama	Cret.	Taxon.	Pessagno E. A Jr 1972
Amer.N. Calit. Gr.Valley California	L.Cret.	Strati Taxon.	Pessagno E. A. Jr 1976
Amer.N. Calif. Gr.Valley Franciscan	E.Cret.	Strati Taxon.	Pessagno E. A. Jr 1977b
Amer.N. Calit. Great Valley	L.Cret.	Taxon.	Pessagno E. A. Jr 1970

LOCATION	AGE	TOPIC	AUTHOR
Amer.N. Calif. Klamath	Perm.-Tr.	N.Sp. Paleoenvir.	Noble P. & Renne P. R. 1988
Amer.N. Calif. S.Klamath		Strati	Irwin W. P. *et al.* 1977
Amer.N. Calif. Tethys Europe (Italy, Spain, France)	Pzc-Czc	Skelet.	De Wever P. 1986
Amer.N. California,	M.-L.Jur.	Taxon.	Pessagno E. A. Jr & Blome C. D. 1982
Amer.N. California	L.Cret.	Taxon.	Campbell A. S. & Clark B. L. 1944
Amer.N. Canada (Br.Columb.)	Devon.-Jur.	Taxon.	Cordey F. & De Wever P. 1988
Amer.N. Can. (Br Columb.) CacheCreek	Jur.	Strati	Cordey F. *et al.* 1987b
Amer.N. Can. (Br.Columb.) CacheCreek	Perm.-Jur.	Strati	Cordey F. *et al.* 1987a
Amer.N. Canada Alberta	Cret.		Wall J. H. 1975
Amer.N. Canada Queen Charlotte	Tr. (L. Nor.)		Carter E. S. 1988
Amer.N. Canada Queen Charlotte	Eart.-Mid.Jur.	Biostr. Taxon.	Carter E. S. *et al.* 1988
Amer.N. Canada Queen Charlotte	Eart.-Mid.Jur.	Biostr. Taxon.	Carter E. S. 1985
Amer.N. Can. Queen Charlotte (Kunga)	L.Tr.	Strati	Carter E. S. *et al.* 1989
Amer.N. Colorado, Kansas	Cret.	Strati Taxon.	Bergstresser T. J. 1983
Amer.N. E.Alaska	L.Tr.	NSG N.Sp.	Robinson B. E. & Pessagno E. A. Jr 1988
Amer.N. E.Atlantic Europe	Cret.	Strati Taxon.	Foreman H. P. 1977
Amer.N. E.Oregon (Blue-Mts E.Oregon)	Pzc-Mzc	Environ. Biostr.	Blome C. D. *et al.* 1986
Amer.N. E.Oregon W.Idaho.	Tr.-Cret.	Biogeo. Ecolo. Taxon.	Pessagno E. A. Jr & Blome C. D. 1986
Amer.N. E-C.Oregon	Lias.-Dog.	Taxon. Cladist.	MacLeod N. 1988
Amer.N. East-C.Oregon	Tr.-E.Jur.	Taxon.	Yeh K. Y. 1987
Amer.N. East-C.Oregon.	Mzc		Yeh K.-H. 1989
Amer.N. East-C.Oregon.	Tr.		Yeh K.-Y. 1988
Amer.N. Europe E.Atlantic	Cret.	Strati Taxon.	Foreman H.-P. 1977
Amer.N. NW.Nevada	Jur.-Cret.	Ophiol. Strati	Sosson M. *et al.* 1984
Amer.N. Oregon	L.Tr.	Taxon. Strati	Blome C. D. 1983
Amer.N. Oregon British Columbia.	L.Tr.-Jur.	Taxon. Strati	Pessagno E. A. Jr & Blome C. D. 1980
Amer.N. S.Alaska E.Oregon.	Mid.Jur. (Callov.)	Taxon. Strati	Blome C. D. 1984a
Amer.N. SW Oregon Strati	Mzc		Carayon V. *et al.* 1984
Amer.N. SW.Oregon Klamath	Tr.	Strati Ophiol.	Roure F. & De Wever P. 1983
Amer.N. USA Canada	Jur.	Taxon.	Pessagno E. A. Jr *et al.* 1986
Amer.N. W.Calif.	L.Mzc		Seiders V. M. & Blome C. D. 1988
Amer.NW. Amer.N. Calif.	L.Jur.	Strati	Pessagno E. A. Jr *et al.* 1984
Amer.S. Argentina (Neuquén)	Jur.-Cret.	Biostr.	Pujana I. 1988
Amer.S. Feuerland	Cret.		Richter M. 1925
Amer.S. Tripoli (Chile)	Czc Mzc	Taxon. N.Sp. Strati	Frenguelli J. 1941
Asia Austral.		Sedim.	Kobayashi T. 1944
Asia China Himalaya Tibet Gyangze S.Xizang (Tibet)	Cret.		Wu H.-R. & Li H. S. 1982
Asia China Himalaya Tibet Xizang	Cret.		Wu Hao-ruo *et al.* 1977
Asia China Himalaya Tibet Yarlung Zangpo			Wu Hao-ruo 1980
Asia China Japan Sikhote-Alin	Tr.-Jur.		Kojima S. 1989
Asia China S.Tibet	L.Jur.-E.Cret.		Wu H. 1988
Asia China S.Xizang	Tr.-E.Jur.	Taxon.	Yigang W. & Yujing W. 1976
Asia China S.Xizang	Mzc?	Plankton	Wang Yujing & Sheng Jinzhang 1982
Asia China Sea			Tan Zh. & Su X. 1982
Asia China Tibet Himalaya Zangbo Xizang	Cret.	Ophiol.	Wu Hao-ruo & Wanming D. 1980
Asia China Tibet S.Xizang	Cret. Cenom.	Taxon. N.Sp.	Wu H. R. 1986
Asia China Tibet Xizang	Jur. E.Tithon.	Taxon.	Li H. S. 1986
Asia China Tibet Xizang	E.Jur. (L.Pliensb)		Li H. S. 1988

LOCATION	AGE	TOPIC	AUTHOR
Asia China Xish Island		Taxon. N.Sp.	Xinghui S. 1982
Asia China.E		Strati	Zhiyuan T. & Tsorun T. 1976
Asia China.NE.	Tr.-Jur.		Kojima S. & Mizutani S. 1987
Asia China.NE	Tr.-Jur.		Satoru K. & Mizutani S. 1987
Asia ex-USSR Crimea		Ecolo.	Tshedla D. M. 1981
Asia ex-USSR E.Sakhalin	Tr.	Strati	Bragin N. Ju. 1985
Asia ex-USSR NW.Uzbek.	Mzc?		Averburg N. V. & Kestner F. F. 1973
Asia Himalaya Tibet, Ladakh	Mzc Eoc.	Biostr. Strati Ophiol.	Colchen M. *et al.* 1987
Asia India		Ophiol.	Ghosh S. *et al.* 1984
Asia Indones. Borneo Molukken	Jur.-Cret.		Tan Sin-Hok 1927
Asia Indones.		Strati Taxon.	Tan Sin Hok 1931
Asia Japan		Strati	Ichikawa K. 1946
Asia Japan	Mzc? Pzc? Czc?	Diagen. Silica	Nagata K. 1986
Asia Japan	L.Jur.-Cret.	Taxon. Strati	Nakaseko K. & Nishimura A. 1981
Asia Japan	L.Tr.	Taxon. Strati	Nakaselo K. & Nishimura A. 1980
Asia Japan	L.Jur.	Taxon. Strati	Matsuoka A. 1984a
Asia Japan	Cret.	Taxon. Strati	Nakaseko K. *et al.* 1979a, b
Asia Japan		Sedim. Melange Strati	Nakazawa K. *et al.* 1983b
Asia Japan	Gen.geol.	Strati	Nakaseko K. *et al.* 1983
Asia Japan	L.Tr.-E.Jur.	Biostrl	Igo H. & Nishimura H. 1984
Asia Japan	Jur.	Zonation Strati	Matsuoka A. & Yao A. 1986
Asia Japan	Czc Mzc		Kobayashi T. & Kimura T. 1944a
Asia Japan	Jur.-Cret.	Taxon. N.Sp.	Ichikawa K. & Yao A. 1976
Asia Japan	Mzc	Strati	Ichikawa K. 1986
Asia Japan	Pzc-Czc		Ichikawa K. 1953
Asia Japan	Permo-Tr.	Evolu.	Kobayashi T. & Kimura T. 1944b
Asia Japan	Mzc		Mizutani S. 1987
Asia Japan	Tr.-Jur.		Kido S. 1982
Asia Japan	Mzc Pzc	Gener.	Kimura T. 1944c
Asia Japan	Tr.-Cret.	Sedim. Strati	Matsuoka A. 1983b
Asia Japan	Perm.-Tr.	Strati	Koike T. *et al.* 1974
Asia Japan	Mzc? Czc	Strati	Nakaseko K. 1979b
Asia Japan	Czc	Geol. Strati	Nakaseko K. *et al.* 1979
Asia Japan	Lias.	Strati	Isozaki Y. & Matsuda T. 1985
Asia Japan	Cret.	Strati Correl.	Nakaseko K. 1979
Asia Japan	Jur.	Strati Taxon.	Isozaki Y. *et al.* 1981
Asia Japan	Tr.-Jur.	Taxon.	Yao A. & Ichikawa K. 1969
Asia Japan	Jur.-Cret.	Extinc. Taxon. Strati	Matsuoka A. 1986a
Asia Japan	Jur.	Biostr.	Yao A. 1986
Asia Japan			Sugano K. & Nakaseko K. 1970
Asia Japan	Jur.	Environ.	Sunouchi H. *et al.* 1982
Asia Japan	Tr.-Jur.	Strati Taxon.	Yao A. 1982b
Asia Japan	L.Cret-Czc	Strati	Nakaseko K. *et al.* 1965
Asia Japan			Kimura T. 1944a
Asia Japan	Jur.	Taxon. Strati	Mizutani S. *et al.* 1984
Asia Japan	Jur.-Cret.	Strati	Fujimoto H. 1933b
Asia Japan	Cret.		Murata M. *et al.* 1982
Asia Japan	Carboniferous-Jur.	Strati	Naka T. & Ishiga H. 1987
Asia Japan	Tr.-Jur.	Silica Geoch.	Kakuwa Y. 1987
Asia Japan	Pzc-Mzc	Strati	Koike T. & Takashima K. 1983
Asia Japan		History	Sugano K. 1975
Asia Japan	Mzc		Okimura Y. *et al.* 1986

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Asia Japan	Jur.	Taxon. Strati	Wakita K. 1982
Asia Japan		Strati	Suzuki J. 1939
Asia Japan	Jur.	Taxon. Evolu.	Takemura A. & Nakaseko K. 1983
Asia Japan	Mzc	Sedim.	Sugano K. 1986
Asia Japan	Tr.	Taxon.	Sato T. *et al.* 1982
Asia Japan		Strati Plankton	Takemura A. 1980
Asia Japan	Jur.		Sashida K. *et al.* 1982a
Asia Japan	E.Jur.		Sashida K. *et al.* 1986
Asia Japan	Tr.-Jur.	Taxon.	Sato T. & Nishizono Y. 1983
Asia Japan	L.Cret.	Geol.	Kurimoto C. 1982
Asia Japan			Sugano K. & Nakaseko K. 1968
Asia Japan	Jur.	Taxon.	Takemura A. & Nakaseko K. 1982b
Asia Japan	Jur.	Taxon.	Takemura A. & Nakaseko K. 1982a
Asia Japan	Jur.	Strati	Matsuoka A. 1985a
Asia Japan	M.Jur.		Yokota S. & Sano H. 1986
Asia Japan	Tr.		Takashima K. & Koike T. 1982
Asia Japan	Jur.	Taxon.	Takemura A. & Nakaseko K. 1982c
Asia Japan	Jur.	Taxon. Strati	Matsuoka A. 1986c
Asia Japan	Mzc Czc	Strati Gen.geol.	Takeshita T. 1982
Asia Japan		Taxon. Skelet. Evolu.	Takemura A. & Nakaseko K. 1986
Asia Japan (Shikoku) Tethys Italy	Mid.Jur.-Earl.Cret.	Biostr. Strati	Aita Y. 1987
Asia Japan Boso Chiba	Czc? Mzc?		Kanomata N. & Iwashita F. 1964
Asia Japan Chichibu		Taxon. Strati	Fujimoto H. 1939
Asia Japan Chichibu	Mesozoic	Strati	Matsuoka A. 1986b
Asia Japan Chichibu	Pzc-Mzc	Gen.geol.	Owada K. & Saka Y. 1982
Asia Japan Chichibu Kyushu	Tr.-Jur.	Biostr.	Sato T. *et al.* 1986
Asia Japan E.Hokkaido	Cret.		Kiminami K. *et al.* 1983
Asia Japan E.Shikoku	Mzc	Strati	Ishida K. 1986a, b
Asia Japan Gifu	Tr. Jur.		Wakita K. & Isomi H. 1986
Asia Japan Hidaka	L.Cret.		Iwata K. & Kato Y. 1986
Asia Japan Hokkaido		Strati	Nagata K. 1982
Asia Japan Hokkaido	Jur.-E.Cret.	Strati	Ishizuka H. *et al.* 1984
Asia Japan Hokkaido	Cret	Strati Gen.geol.	Takotani Y. 1982
Asia Japan Hokkaido	E.Cret.	Strati	Minoura N. *et al.* 1982
Asia Japan Hokkaido	Aptian		Okada H. *et al.* 1982
Asia Japan Hokkaido	Cret.-Czc (Mioc.-Ouater.)	Strati	Nagata K. 1979
Asia Japan Hokkaid	Cret.		Tajika J. & Iwata K. 1983
Asia Japan Japan.C.	L.Cret.		Iyota N. *et al.* 1984
Asia Japan Kochi	Jur.	Biostr. Strati	Aita Y. 1982
Asia Japan Kyushu	Mzc		Nishizono Y. *et al.* 1982
Asia Japan Kyushu	Mzc	Sedim.	Nishizono Y. & Murata M. 1983
Asia Japan Kyushu	L.Jur.		Tanaka H. *et al.* 1985
Asia Japan N.Hokkaido	E.Cret.	Strati	Igo H. *et al.* 1987
Asia Japan N.Shimanto	Cret.		Okamura M. 1981
Asia Japan N.Shimanto	L.Cret.		Yamauchi M. 1982
Asia Japan N.Shimanto Shikoku	L.Jur.-Earl.Cret.	Strati	Aoki T. 1982
Asia Japan Okinawa	Cret.	Taxon.	Fujita H. 1983
Asia Japan Okinawa			Ujiie H. & Hashimoto Y. 1983
Asia Japan S.Shikoku		Sedim. Gen.geol.	Yehara S. 1926
Asia Japan Sakawa Tosa			Kimura T. 1944b
Asia Japan Sambagawa	Jur.		Kobayashi T. 1941

LOCATION	AGE	TOPIC	AUTHOR
Asia Japan SE.Kanto	Czc? Mzc	Taxon. Strati	Ichikawa K. 1950
Asia Japan Shikoku	Mzc		Nakagawa C. & Nakaseko K. 1977
Asia Japan Shikoku	L.Jur.-Cret.	Strati	Nakagawa C. *et al.* 1980
Asia Japan Shikoku	Jur.	Biostr. Strati	Aita Y. 1985
Asia Japan Shikoku			Suyari K. & Kuwano Y. 1986
Asia Japan Shikoku	Jur.	Taxon. Strati	Matsuoka A. 1982a
Asia Japan Shikoku	Tr.-Jur.	Taxon.	Yehara S. 1927
Asia Japan Shikoku	Tr.-Jur.	Strati Sedim.	Ishida K. 1985
Asia Japan Shikoku	E.Cret.		Okamura M. & Uto H. 1982
Asia Japan Shikoku	Cret.		Okamura M. & Matsugi H. 1986
Asia Japan Shikoku	L.Cret.		Okamura M. *et al.* 1982
Asia Japan Shimanto	Cret.	Strati	Aoki T. & Tashiro M. 1982
Asia Japan Shimanto	Mzc		Suyari K. 1986a,b
Asia Japan Shimanto Shikoku	Mzc	Strati	Suyari K. & Yamasaki T. 1988
Asia Japan SW.Hokkaido	Jur.	Tecton.	Ishiga H. & Ishiyama D. 1987
Asia Japan Tethys	L.Jur.-Earl.Cret.		Aita Y. & Okada H. 1986
Asia Japan, Tethys Europe ex-USSR Amer.N. Calif.	Mzc	Bioz.	Vishnevskaya V. S. 1985
Asia Japan W.Shikoku. Chichibu	Jur.		Kashima N. 1986
Asia Japan.C.	Jur.	Taxon. Strati	Mizutani S. & Kido S. 1983
Asia Japan.C.	Tr.	Radt Sedim.	Sugisaki R. *et al.* 1982
Asia Japan.C.	E.Cret.		Wakita K. 1988
Asia Japan.C.			Otsuka T. 1986
Asia Japan.C.	Tr.-Jur.	Taxon.	Yao A. *et al.* 1980
Asia Japan.C.	E.Jur.	Taxon.	Sashida K. 1988
Asia Japan.C.	L.Tr.-Earl.Jur.	Biostr.	Yoshida H. 1986
Asia Japan.C.	M.Jur.	Biozon. Biostr.	Matsuoka A. 1988
Asia Japan.C.	Jur.	Taxon. Strati	Mizutani S. *et al.* 1982a
Asia Japan.C. (Mino terr.)	Jur. Mzc	Strati	Adachi M. 1982
Asia Japan.C. Fukui	Jur.		Hattori I. 1987
Asia Japan.C. Fukui	Lias.-Dog.		Hattori I. 1988
Asia Japan.C. Gifu	Mzc	Sedim.	Wakita K. & Okamura Y. 1982
Asia Japan.C. Inuyama	Lias.	Taxon.	Hori R. & Yao A. 1988
Asia Japan.C. Inuyama	Earl.Jur.		Hori R. 1986
Asia Japan.C. Kanto	Cret.		Hisada K.-I. *et al.* 1986
Asia Japan.C. Kanto	Jur.-Cret.		Hisada K.-I & Kishida Y. 1986
Asia Japan.C. Mino	Mzc	Genesis Silica Radt Environ.	Hattori I. 1984
Asia Japan.C. Sambagawa		Sedim. Diagen.	Huzimoto H. 1938
Asia Japan.C.	Perm.-Jur.		Kojima S. 1982
Asia Japan.C.	Tr.	Taxon. Strati	Mizutani S. *et al.* 1981b
Asia Japan.C.	L.Tr.-E.Jur.	Strati	Kishida Y. & Hisada K. 1985
Asia Japan.C.	M.Tr.-E.Jur.	Taxon.	Yao A. 1982a
Asia Japan.C.	Jur.	Sedim. Radt	Wakita K. 1983
Asia Japan.C.	L.Jur.-Cret.	Strati	Yamamoto H. 1983
Asia Japan.C.	Jur.	Gen.geol.	Wakita K. 1983
Asia Japan.C.		Strati	Kishida Y. & Hisada K. 1986
Asia Japan.C.	Jur.	Strati	Mizutani S. *et al.* 1981a
Asia Japan.C.	Cret.	Taxon.	Sashida K. *et al.* 1984
Asia Japan.C.	Mzc	Sedim. Taxon.	Yoshimura M. *et al.* 1982
Asia Japan.C.	Tr.-Jur.	Taxon.	Yao A. 1972
Asia Japan.C.	Tr.-Jur.	Taxon.	Yao A. 1979
Asia Japan.C.	E.Tr.	Taxon.	Sashida K. 1983

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Asia Japan.C.	Tr.-Jur.	Taxon. Strati	Mizutani S. & Koike T. 1982
Asia Japan.C.	Cret.	Taxon. Strati	Iwasaki T. *et al.* 1984
Asia Japan.C.		Strati	Kido S. *et al.* 1982
Asia Japan.C.	Jur.	Strati	Mizutani S. 1981
Asia Japan.C.	L.Tr.-Mid.Jur.	Strati Tecto.	Hattori I. & Yoshimura M. 1983
Asia Japan.N. Hokkaido	L.Jur.-E.Cret.	Taxon. N.Sp.	Kawabata K. 1988
Asia Japan.N. Hokkaido	L.Jur.	Ophiol.	Ishizuka H. *et al.* 1983
Asia Japan.N. Hokkaido	E.Cret.		Kanie Y. *et al.* 1981
Asia Japan.N. NE.Hokkaido	Jur.-Cret.		Iwata K. *et al.* 1983a,b
Asia Japan.NE.	Mzc		Matsuoka A. 1987
Asia Japan.SW.	Perm.-Tr.		Ishiga H. & Kusu T. 1986
Asia Japan.SW.	Tr.-Jur.	Taxon.	Yao A. *et al.* 1982
Asia Japan.SW.	Jur.		Saka Y. 1983
Asia Japan.SW.	Tr.-Jur.	Taxon.	Yao A. 1983
Asia Japan.SW.	Mesozoic	Strati	Nakaseko K. 1981
Asia Japan.SW.	L.Jur.	Taxon. Strati	Matsuoka A. & Yao A. 1985
Asia Japan.SW.	Jur.	Strati	Matsuoka A. 1984b
Asia Japan.SW.	L.Tr.-Earl.Jur.	Biostr	Hori R. 1988
Asia Japan.SW.	Jur.(Dog.)	Strati	Imoto N. *et al.* 1982
Asia Japan.SW.	Tr.-Jur.	Taxon.	Yao A. 1981
Asia Japan.SW.		Strati	Ichikawa K. *et al.* 1985
Asia Japan.SW.	Perm.	Envir.	Imoto N. 1984a
Asia Japan.SW.	Mzc	Envir. Radt	Imoto N. 1984b
Asia Japan.SW.	M.Jur.	Taxon. Strati	Matsuoka A. 1985b
Asia Japan.SW.	L.Tr.	Taxon. N.Sp.	Nakaseko K. & Nishimura A. 1979
Asia Japan.SW.	Tr.-Jur.	Strati	Kishida Y. & Sugano K. 1982
Asia Japan.SW.	Permian		Isozaki Y. 1986
Asia Japan.SW.	Tr.	Taxon. Strati	Isozaki Y. & Matsuda T. 1980
Asia Japan.SW.	Tr.-Jur.	Strati	Matsuda T. & Isozaki Y. 1982
Asia Japan.SW.	Mid.L.Jur.	Taxon. Strati	Matsuoka A. 1982b
Asia Japan.SW.	Jur.	Strati	Hayasaka Y. *et al.* 1983
Asia Japan.SW.	Cret.	Envir.	Nakazawa K. *et al.* 1983a
Asia Japan.SW.	Mzc	Strati	Kamon M. & Taketomi H. 1982
Asia Japan.SW. E.Shikoku		Gen.geol.	Yanai S. 1983
Asia Japan.SW. Kii	Cret.	Taxon. Strati	Matsuyama H. *et al.* 1982
Asia Japan.SW. Shikoku	L.Jur.	Taxon. Strati	Matsuoka A. 1986d
Asia Japan.SW. Shikoku	M.L.Jur.	Strati	Matsuoka A. 1983a
Asia Japan.SW. Shikoku Awaji	Czc Mzc		Yamasaki T. 1987
Asia Japan.SW. Shikoku	Tr.-Jur.	Strati	Ishida K. 1983
Asia Pacif. Indones. C.Celebes	Mzc		Hinde G. J. 1917
Atlant.		Taxon. DSDP	Riedel W.-R. 1971a
Atlant.	Cret.	Biostr.	Cita M. B. *et al.* 1970
Atlant.	M.Cret.	Sedim. Gen.geol. Strati	Schaaf A. 1985
Atlant.	Czc Mzc	Taxon.	Ehrenberg C. G. 1854
Atlant. Carib. (Bahamas)	Mid.Jur.-Earl.Cret.	Strati	Baumgartner P. O. 1983
Atlant. Carib. (La Desirade, Les Antilles)	Earl.Cret.		Bouysse P. *et al.* 1983
Atlant. Europe			Swain F. M. 1977
Atlant. Europe N.Sea.	L.Jur.-E.Cret.	Review Biostr.	Dyer R. & Copestake P. 1989
Atlant.C. Carib. Barbados	Mzc		Ehrenberg C. G. 1846
Atlant.NE. (off Africa)	Cret.	DSDP41	Foreman H. P. 1978b
Atlant.SE.	Cret.	DSDP40 Taxon. Strati	Foreman H. P. 1978a
Atlantic NE.Mediter.	Cret.Quatern.	DSDP13 Taxon. Strati	Dumitrica P. 1973

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Atlantic E. Europe Amer.N.	Cret.	Strati Taxon.	Foreman H. P. 1977
Austral. Indones. New Guinea		Strati	Crespin I. 1958
Canada (Queen-Charl.) Calif. E-C.Oregon	Lias. Dog.	Taxon.	Pessagno E. A. Jr & Whalen P. A. 1982
DSDP16	Mzc-Czc	Strati	Dinkelman M. G. 1973
Europe Amer.N. E.Atlantic	Cret.	Strati Taxon.	Foreman H. P. 1977
Europe C. Poland	Cret.	Morphol.	Gorka H. 1988
Europe E.Atlantic Amer.N.	Cret.	Strati Taxon.	Foreman H. P. 1977
Europe England (Kimmeridge)	Jur. (Kimm.)	Boreal	Downie C. 1956
Europe France (Ardèche)	Late Tithon.	Taxon.	Cayeux L. 1896
Europe France (Larzac)	Mzc		Bergounioux F. M. 1950
Europe France (Paris Basin.) Belgium	Mzc	Chalk Sedim.	Cayeux L. 1897
Europe Italy Sicily	M.Jur.		Kito *et al.* 1990
Europe	Mzc	Taxon. Evolu. Strat. Techn.	De Wever P., Riedel W. *et al.* 1979b
Europe N.France	Jur. (Oxf.), Eoc.		Cayeux L. 1891
Europe N.Germany	Cret.	Taxon.	Zittel K. A. 1876
Europe Poland Krakau	L.Jur.		Wisniowski T. 1889
Europe Slovak. Czcek. (Meliata, Silica, Slovak Karst)	Tr.-Jur.	Ophiol. Radt	Dumitrica P. & Meilo J. 1982
Europe Turkey	Lias.	Taxon.	Pessagno E. A. Jr & Poisson A. 1981
ex-USSR	Mzc Czc?	Strati	Zhamoida A. I. 1975
ex-USSR	Mesozoic	Strati	Zhamoida A. I. 1972
ex-USSR	Pzc Mzc	Taxon.	Afanasieva M. S. 1986
ex-USSR	Mzc	Strati	Zhamoida A. I. 1981
ex-USSR	Mesozoic	Strati	Zhamoida A. I. 1961
ex-USSR	Mzc		Zhamoida A. I. & Kazintsova L. 1981
ex-USSR	Cret.	Biostr.	Kazintsova L. & Vishnevskaya V. 1988
ex-USSR	Cret.	Strati	Rundyova N. P. & Jinoridze N. 1975
ex-USSR	Cret.?	Taxon. N.Sp. Strati	Vishnevskaya V. S. 1985a
ex-USSR	Cret.	Taxon. Strati	Vishnevskaya V. S. 1981b
ex-USSR	Cret. Cenom.		Kazintsova L. I. 1981
ex-USSR	Mzc	Taxon. Skelet.	Vishnevskaya V. S. 1981c
ex-USSR Amer.N. Calif, Asia Japan, Tethys Europe	Mzc	Bioz.	Vishnevskaya V. S. 1985
ex-USSR Carpath. Ukrain.	Jur.	Strati	Lozynyak P. Yu. 1981
ex-USSR Carpath. Ukrain.	Cret.		Lozynyak P. Yu. 1975
ex-USSR E.-Sakhalin	Mzc	Strati	Zhamoida A. I. 1968
ex-USSR E.Sakhalin	L.Cret.		Kazintsova L. 1985
ex-USSR E.Siber. Sikhote-Alinj	Mzc		Eliseeva V. K. *et al.* 1976
ex-USSR Far East	Cret.	Taxon. Strati	Vishnevskaya V. S. 1981a
ex-USSR Greater & Lesser Caucasus	L.Jur.-Cret.	Biostr.	Vishnevskaya V. S. 1988a-c
ex-USSR Kamchatka			Runeva N. P. 1975
ex-USSR Kamchatka Asia			Vishnevskaya V. S. & Bernard V. V. 1986
ex-USSR Kazakhstan	Czc? Mzc?	Strati	Pupyshev N. A. & Lipman R. 1973
ex-USSR Koriak	Mzc	Strati	Bogdanov N. A. *et al.* 1982
ex-USSR Koryak	Mzc	Strati	Vishnevskaya V. S. *et al.* 1981
ex-USSR Koryaksk	Valanginian	Strati	Dundo O. P. & Zhamoida A. I. 1963
ex-USSR Lesser Caucasus	Mzc	Strati	Zhamoida A. I. *et al.* 1976
ex-USSR Mid.Asia	Mzc		Tshedia D. M. 1984
ex-USSR N.Pacif. Bering Polar	M.L.Cret.	Biozon. Strati Environ.	Vishnevskaya V. S. 1986
ex-USSR Olutor	Cret.-Czc	Strati	Vishnevskaya V. S. 1984a, b
ex-USSR Olyutor Koryak	Cret.		Vishnevskaya V. S. 1987a, b

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ex-USSR Russia	Pzc-Mzc	Gener.	Lipman R. Kh. 1976
ex-USSR Russia	Mzc	Evolu. Taxon.	Lipman R. Kh. 1975b
ex-USSR Russia	Jur.-Cret.	Strati	Lipman R. Kh. 1979b
ex-USSR Russia	Paleogene-L.Cret.	Strati	Lipman R. Kh. 1975a
ex-USSR Russia	L.Cret.	Taxon.	Lipman R. Kh. 1952
ex-USSR Russia Far East	Mzc		Lipman R. Kh. 1953
ex-USSR Russia W.Siberian Turgaisk N.Peri-Aral	L.Cret.		Lipman R. Kh. 1962
ex-USSR Sakatina Kamtchatka	Mzc?		Runeva N. P. 1981
ex-USSR Sakhalin	Mesozoic	Strati	Zhamoida A. I. 1969
ex-USSR Siber. Russia	Czc Mzc		Lipman R. Kh. 1960
ex-USSR Sikhote	Mesozoic	Strati	Zhamoida A. I. 1988
ex-USSR Sikhote-Alin.	Mzc		Tikhomirova L. B. 1975
ex-USSR Tadzhik	Cret. Campan.	Taxon. N.Sp.	Goltman E. V. 1984
ex-USSR Tadzhik	Cret. Senon.	Evolu.	Goltman E. V. & Babaeva B. 1985
ex-USSR Tadzhiksk	Cret. Senon. Quater.	Strati	Goltman E. V. 1981
ex-USSR Tadzhiksk	Cret. (Campan. Maastr.)		Goltman E. V. 1973
ex-USSR Tadzhiksk		Strati	Goltman E. V. 1975
ex-USSR Tethys Carpath.	Earl.Cret.		Tikhomirova L. B. 1983
ex-USSR Tethys Caucasia	Jur.		Tikhomirova L. B. 1981
ex-USSR Timan-Ural	E.Kimm.		Kozlova G. E. 1971
ex-USSR Ukrain. Carpath.	Cret.		Kazintsova L.I. 1984
ex-USSR Urals	Cret.	Biozon.	Amon E. O. 1988
ex-USSR W.Siberia	L.Cret.-Eocene		Kozlova G. E. & Gorbovets A. 1966
ex-USSR W.Siberia	Cret. Turon.	Strati	Amon E. O. 1985
Indian S.	Cret.		Riedel W. R. & Sanfilippo A. 1974
Mediter.	M.Cret.	Ecology Biostr.	Thurow J. & Kuhnt W. 1988
Mid.East Israel	Earl.Cret.-Czc		Reiss Z. 1952
N.Africa	Turon.	Anoxy	Thurow J. 1988
Pacif Indones.	Czc Mzc	Sedim.	Hinde G. J. 1897
Pacif.	Cret.	Strati Taxon.	Schaaf A. 1984b
Pacif.	Cret.	Strati Envir. Taxon.	Schaaf A. 1984a
Pacif.		Strati DSDP	Riedel W. R. 1981
Pacif. Amer.C.		Strati	White M. P. 1928
Pacif. Austral.	Pzc-Mzc	Tecton.	Flood P. G. 1988
Pacif. Austral.	Mzc	Sedim. Envir.	Fenton M. W. *et al.* 1982
Pacif. Australia	Czc? Mzc? Pzc?	Sedim.	Hinde G. J. 1893
Pacif. Indones. Borneo	Cret.		Hinde G. J. 1900
Pacif. Indones. Borneo	Tr.	Taxon.	Hinde G. J. 1908
Pacif. Indones. Celebes	Mzc?		Hojnos R. 1934
Pacif. Mariana Leg 60	Cret.	Strati DSDP	Kling S. A. 1982
Pacif. New Zealand	L.Tr.		Blome C. D. *et al.* 1987
Pacif. New Zealand	Jur.		Feary D. A. & Hill P. H. 1978
Pacif. New Zealand	Jur.-Cret.	Strati	Feary D. A. & Pessagno E. A. Jr 1980
Pacif.N.	Cret.	Strati Taxon. DSDP32	Foreman H. P. 1975
Pacif.SW.		Plankton Geograph.	Stevens G. R. 1980
Pacific Mid.	Cret. Campan.	Taxon. DSDP	Empson-Morin K. M. 1981
Tethys	Tr.-Cret.	Taxon. Evolu.	De Wever P. 1984b
Tethys	Jur.-Cret.	Taxon.	Fischli H. 1916
Tethys	Mid.Jur.-Earl.Cret.	Strati Taxon	Baumgartner P. O. 1984

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Tethys	Mzc-Czc	Taxon. Evolu.	Dumitrica P. 1983a
Tethys	Jur.	Environ. Sedim. Biostr	Baumgartner P. O. 1987
Tethys	Mid.-Tr.	Taxon. Evolu.	Dumitrica P. 1983b
Tethys	Tr.-Jur.	Taxon. N.Sp.	Kozur H. 1984b
Tethys	Tr.-Jur.	N.Sp. Taxon.	Kozur H. 1984d
Tethys	Mid.Tr.	Taxon. N.Sp.	Dumitrica P. 1982b
Tethys	Tr.	Taxon. N.Sp.	Dumitrica P. 1982a
Tethys		Diagen. Sedim. Silica	Hattori I. 1989
Tethys			Kito N. & De Wever P. 1988
Tethys	Tr.-Cret.	Taxon. Evolu. Phylogen.	De Wever P. & Origlia I. 1984
Tethys	Tr.-Cret.	Taxon. Evolu. Phylogen.	De Wever P. & Origlia I. 1983
Tethys Alpes France Ligurian	Jur.	Strati Ophiol.	De Wever P. & Caby R. 1981
Tethys Alps Austria	Jur.	Taxon. Strati	Muzavor S. N. X. 1977
Tethys Alps Austria N.Kalkalpen	L.Jur-E.Cret.	Taxon. Strati	Holzer H.-L. 1980
Tethys Alps Europe	Mzc	Taxon.	Donofrio D. A. & Mostler H. 1978
Tethys Alps Italy	Jur.-Cret.	Strati Taxon. Radt	Kocher R. N. 1981
Tethys Alps N.Italy (Recoaro) Austria	L.Tr.	Taxon. N.Sp.	Lahm B. 1984
Tethys Alps NW.Carpath. Klippen Z.	Mzc		Hojnos R. 1929
Tethys Amer.C.	Jur.-Cret.	Radt	De Wever P. *et al.* 1986a
Tethys Budva (Montenegro, Yugoslavia)	Jur.-Cret.	Taxon.	Gorican S. 1987
Tethys Bulgaria Trekljano S.W.Bulgaria			Zagorcev I. & Tikhomirova L. 1986
Tethys Carpath.	L.Jur.	Biostr.	Ozvoldova L. & Petercakova M. 1987
Tethys Carpath. Klippen	Jur.		Ozvoldova L. & Sykora M. 1984
Tethys Carpath. Klippen	L.Jur.		Ozvoldova L. 1975
Tethys Carpath. Klippen	L.Jur.		Ozvoldova L. 1979a
Tethys Carpath. Mediter. Lesser Caucas.	L.Jur.-Cret.		Tikhomirova L. B. 1984
Tethys Carpath. Slovak Klippen Podbiel	Jur.		Ozvoldova L. 1979b
Tethys Cret.	Jur.	Taxon. Evolu.	De Wever P. 1983
Tethys Cyprus Oman	Jur.-Cret.	Strati	Blome C. D. & Irwin W. P. 1985
Tethys Cyprus. (Troodos)	Cret.-Czc	Strati Envir. Ophiol.	Robertson A. H. & Hudson J. D. 1974
Tethys E.Carpathians S.Alps	Tr.	Taxon. N.Sp. Phylogen.	Dumitrica P. 1982c
Tethys E.Rhodope Bulgaria	E.Cret.	Strati	Lipman R. Kh. & Boyanov I. 1976
Tethys Europe	Cret.		Rüst D. 1887
Tethys Europe	Cret.	Taxon.	Rüst D. 1888
Tethys Europe	Tr.(Ladin.)	Taxon. N.Fam.	Kozur H. 1988
Tethys Europe	Tr.	Taxon.	Kozur H. & Mostler H. 1984
Tethys Europe	Jur.-Cret.	Taxon.	Rüst D. 1898
Tethys Europe	Jur.	Taxon.	Rüst D. 1885
Tethys Europe	Tr.	Taxon.	Rüst D. 1892
Tethys Europe (Italy, Spain, France) Amer.N. Calif.	Pzc-Czc	Skelet.	De Wever P. 1985
Tethys Europe Alps	Tr.	Taxon. N.Sp.	Kozur H. & Mostler H. 1981
Tethys Europe Alps	Oxf.-Kimm.	Strati Envir Taxon. Ophiol.	Schaaf A. *et al.* 1985
Tethys Europe Alps	Tr.-Jur.	Taxon. N.Sp.	Kozur H. & Mostler H. 1979a
Tethys Europe Alps	Tr.	Taxon. N.Sp.	Kozur H. & Mostler H. 1972
Tethys Europe Alps	Tr.-Jur.	Taxon.S N.Sp.	Kozur H. & Mostler H. 1978
Tethys Europe Alps Austria	Tr.	Taxon. N.Sp.	Kozur H. & Mostler H. 1979b
Tethys Europe Alps Austria Kalkalpen Salzburg	L.Jur.	Sedim.	Steiger T. 1981
Tethys Europe Austria Salzburg	Earl.Lias.		Dunikowski E. V. 1882
Tethys Europe Carpath. Meliata-Serie	Pzc-Mzc	Strati	Kozur H. & Mock R 1973
Tethys Europe Corsica	Jur.-Cret.	Ophiol. Strati	De Wever P. *et al.* 1987b

LOCATION	AGE	TOPIC	AUTHOR
Tethys Europe Eastern Rhodops Bulgaria	Earl.Cret.		Boyanov I. & Lipman R. Kh. 1973
Tethys Europe ex-USSR	Mzc	Bioz.	Vishnevskaya V. S. 1985
Amer.N. Calif, Asia Japan			
Tethys Europe Greece	Tr.-Jur.	Strati Envir. Paleogeog.	De Wever P. & Dercourt J. 1985
Tethys Europe Greece Crete	Tr.	Metam. Strati	Kozur H. & Krahl J. 1984
Tethys Europe Greece Ionian	Cellov.-Tithon.		Karakitsios V. *et al.* 1988
Tethys Europe Greece Italy Sicily Turkey	Tr. Lias.	Taxon. Strati	De Wever P. 1982b
Tethys Europe Greece Pindos	Jur.-Cret.	Strati	De Wever P. & Origlia I. 1982a
Tethys Europe Greece Pindos	Lias.	Taxon. Radt	De Wever P. & Origlia I. 1982b
Tethys Europe Greece Pindos-Olonos	Dogg.-Malm.	Strati	De Wever P. & Cordey F. 1984
Tethys Europe Greece Pindos-Olonos	Jur.-Cret.	Taxon. Environ.	De Wever P. & Thiébault F. 1981
Tethys Europe Greece Pindos-Olonos	L.Tr.		Zagorcev I. *et al.* 1989
Tethys Europe Hungary	Mzc		Hojnos R. 1916
Tethys Europe Hungary Mechek	L.Jur.	Sedim. Strati	Nadj I. 1971
Tethys Europe Italy (Euganei)	Cret.	Taxon.	Squinabol S. 1903
Tethys Europe Italy (Euganei)	Cret.	Taxon.	Squinabol S. 1904
Tethys Europe Italy (Lagonegro)	Tr.-Cret.		De Wever P. & Miconnet P. 1985
Tethys Europe Italy	Jur.	dating	Conti M. *et al.* 1988
(Ligur., Apenn.Mt.Alpe)			
Tethys Europe Italy (Veneto)	Cret.	Taxon.	Squinabol S. 1914
Tethys Europe Italy Alpes	Jur.	Ophiol.	De Wever P. *et al.* 1987
Tethys Europe Italy Alps Monginervo	Cret.	Taxon.	Squinabol S. 1912
Tethys Europe Italy Bolognese	Mzc	Taxon.	Neviani A. 1900
Tethys Europe N.Apen. Italy (La Spezia)	Tr./Lias.	Taxon. Strati	Ciarapica G. & Zaninetti L. 1982
Tethys Europe N.Hungary	Jur.(Bajoc.)	Taxon.	Kozur H. 1985
Tethys Europe N.Hungary	Jur.	Taxon.	Kozur H. & Mostler H. 1986
Tethys Europe N.Hungary Rudabanya	Mid.Jur.		Grill H.-J. & Kozur H. 1986
Tethys Europe NW.Yugoslavia	Mid.Tr.	Taxon. Biostr.	Gorican S. 1988
Tethys Europe Romania	Jur.-Cret.	Taxon.	Dumitrica P. 1970
Tethys Europe Russia Urals	E.Perm.	Taxon.	Kozur H. & Mostler H. 1989
Tethys Europe Slovenia (NW Yugosl.)	Ladin.(M.Tr.)	Taxon.	Kolar-Jurkovsek T. 1989
Tethys Europe Slovenia	Tr.-Jur.		Gorican S. & Kolar-Jurkovsek T. 1984
Tethys, Europe Spain, Sicily, SE France	L.Jur.- E.Cret.	Biostr.	Manivit H. *et al.* 1986
Tethys Europe Switzer.	Mzc Czc	Taxon.	Jaccard F. 1909
Tethys Europe	Taxon.	N.Sp., Evolu.	Kozur H. & Mostler H. 1983
Tethys Europe Turkey	Lias.	Taxon.	De Wever P. 1984c
Tethys Europe Turkey	Lias.	Taxon. N.Sp.	De Wever P. 1982a
Tethys Eur. W. Carpath. Kysuca Klippen	Mzc	Biostr	Ozvoldova L. 1988
Tethys Europe W.Carpath.	Mzc Jur.		Kozur H. & Mock R. 1985
Tethys Europe W.Carpaths Meliata	Jur.		Kozur H. & Mock R. 1985
Tethys France Htes-Alpes	L.Jur.-E.Cret.		Turner J. 1965
Tethys German	Dog.		Heitzer I. 1930
Tethys Greece	Late Jur.	Taxon. Strati	Baumgartner P. O. 1980
Tethys Greece	Jur.-Cret.	Radt	Thiébault F. *et al.* 1980
Tethys Greece (Evvoia, E.Greece)	Late Jur.-Earl.Cret.	Strati Taxon.	Baumgartner P. O. & Bernoulli D. 1976
Tethys Greece (Peloponnesus)	Jur.	Strati Sedim.	Baumgartner P. O. 1985
Tethys Greece Argolis	Jur.-Cret.		Baumgartner P. O. 1981
Tethys Greece Epireous	Jur.	Taxon. Strat.	Danelian T. 1989
Tethys Greece Epireous	Jur.-Cret.	Strati	Danelian T. *et al.* 1986
Tethys Greece Europe Asia Amer.	Jur.-Cret.	Radt Climat	De Wever P. 1987
Tethys Greece Hungary	Mid.Jur.-Cret.	Taxon.	Cordey F. 1984
Tethys Greece Italy	L.Jur.-Earl.Cret.	Strati	Baumgartner P. O. 1980

LOCATION	AGE	TOPIC	AUTHOR
Tethys, Greece, Italy Amer.C. Costa Rica	L.Jur.-Earl.Cret.	DSDP	Devos I. 1983
Tethys Greece Italy (Sicily) Amer.C. Costa Rica Indian	Jur.-Cret.	DSDP Taxon. Strati	Origlia-Devos I. 1983
Tethys Greece Italy Lombardia	Jur.-Cret.	N.Sp. Taxon.	De Wever P. 1981c
Tethys Greece Mediter. Karpathos	Cret.		Vinassa de Regny P. E. 1901-02
Tethys Greece Pindos Europe	Jur.-Cret. Baj.(?)-. Tithon	Strati Taxon.	De Wever P. & Cordey F. 1986
Tethys Greece PindosZ. (S.Peloponnes.)	Jur.-Cret.		Thiebault F. *et al.* 1986
Tethys Greece Sicily, Turkey.	Tr.	Taxon. N.Sp.	De Wever P. *et al.* 1979a
Tethys Hungary (Darno)	Tr.	Strati	De Wever P. 1984a
Tethys Hungary Bukk	Jur.	Strati Biogeo	Kozur H. 1984e
Tethys Hungary Carpath. Bükk Meliata Uppony Mecsek	Mzc	Strati	Kozur H. 1984a
Tethys Italy	Mzc-Czc	Taxon.	Vinassa de Regny P. E. 1898a
Tethys Italy (Lombardy, Sicily) Japan (Shikoku)	Mid.Jur.-Earl.Cret.	Biostr. Strati	Alta Y. 1987
Tethys Italy (Sicily)	Jur.-Cret.	Taxon. Biostr.	De Wever P. *et al.* 1986b
Tethys Italy (Sicily)	Late.Jur.-Earl.Cret.	Biostrat. Taxon.	De Wever P. *et al.* 1985
Tethys Italy (Spezia)	Tithon.	Taxon.	Vinassa de Regny P.E. 1899
Tethys Italy Alps E.Carpathians (Rom.)	Tr.	Taxon. N.Sp.	Dumitrica P. 1978c
Tethys Italy Appennine	Jur.		Marcucci M. *et al.* 1987
Tethys Italy Bolognese	Jur.		Vinassa de Regny P. E. 1900
Tethys Italy E.Liguria (Mte Alpe)		Taxon.	Conti M. & Passerini M. 1988
Tethys Italy Europe	Mzc Czc	Taxon.	Neviani A. 1901
Tethys Italy Europe C.Appennine	Cret. (Cenom.-Turon.)	Biostr	Marcucci Passerini M. *et al.* 1988
Tethys Italy France Ligury Europe Alps	Jur.-Cret.	Ophiol. Strati	De Wever P. *et al.* 1987a
Tethys Italy N.Apennine Corsica	Jur.-Cret.	Strati	Conti M. *et al.* 1985
Tethys Italy N.Apennines	Jur.	Stratig. ophiol.	Barrel T. J. 1982
Tethys Italy N.Apennines	Jur.-Cret.	Strati	Conti M. & Marcucci M. 1986
Tethys Italy S.Tuscany		Biostr.	Conti M. 1986
Tethys Italy Spezia	Jur. Tithon.		Vinassa de Regny P. E. 1898b
Tethys Morocco (Rif)	Jur.-Cret.	Paleogeog. Strati Envir.	De Wever P. *et al.* 1985b
Tethys Morocco N.Rif	Jur.-Cret.	Taxon. Strati Radt	El-Kadiri Kh. 1984
Tethys NW Greece Ionian	Jur.	Biostr.	Danelian T. & De Wever P. 1988
Tethys Oman	Permian-Cret.	Biostr.	De Wever P. & Bourdillon C. 1988
Tethys Oman	Cret.	Strati Ophiol.	Beurrier M. *et al.* 1987
Tethys Oman	Perm.-Cret.	Radt Tethys strat.	Bourdillon C. *et al.* 1987
Tethys Oman (Hawasina)	Mzc Permian	Strati Paleogeog.	De Wever P. *et al.* 1988
Tethys Oman (Hawasina)		Strati	Blome C. D. *et al.* 1983
Tethys Oman (Samail N.)	Cret.(Senon.)	Radt Taxon. N.Sp.	De Wever P. & Bourdillon C. 1988
Tethys Oman (Semail)	Cret. Campan.	Strati Taxon. Ophiol.	Schaaf A. & Thomas V. 1986
Tethys Oman (Semail)	Jur.-Cret.	Ophiol.	Tippit P. R. *et al.* 1983
Tethys Oman Hawasina	Mzc		Davis A. G. 1950
Tethys Pannonian Hungary	Mzc	Biogeo Strati	Kozur H. 1984c
Tethys Romania	Jur.-Cret.	Radt	Protescu O. 1933
Tethys Romania Carpath.	Cret.(Cenom.)	Taxon. Strati	Dumitrica P. 1975
Tethys Rotti Europe Italy	Mesozoic	Taxon. Strati	Riedel W. R. 1953
Tethys S.Alps.	Mid.Tr.	Taxon. Strati	Dumitrica P. *et al.* 1980
Tethys Tethys Oman Samail	Cret.(Senon.)	Taxon. Ophiol.	De Wever P. *et al.* 1988
Tethys Turkey	Lias.	Taxon. N.Sp.	De Wever P. 1981b

LOCATION	AGE	TOPIC	AUTHOR
Tethys Turkey	Lias.	Taxon. N.Sp.	De Wever P. 1981a
Tethys Turkey	Mzc	Ophiol.	Bailey E. B. & McCallien W. J. 1953
Tethys W.Carpath. Yugosl.	L.Jur.-E.Cret. (Tithon.-Neocom.)	Sedim.	Misik M. 1973
Tethys W.Slovenia	E.Cret.		Pavsic J. & Gorican S. 1987
Tethys Yugosl.	Mzc	Radt	Obradovic J. & Gorican S. 1987
Tethys Yugoslvia Slovenia	Jur.	Taxon.	Gorican S. 1983
W.Pacif.	E.Cret.	DSDP62 Strati Taxon.	Schaaf A. 1981b
W.Pacif. Indones. Borneo	Mzc	Strati Dating Ophiol.	Leong K. M. 1975
W.Pacif. Palawan Block, Philippines	L.Pzc-Earl.Mzc	Strati	Cheng Y.-N. 1989
W.PAcif.E.Australia (New England)	Pzc Mzc		Aitchison J. 1988
W.Pacific, DSDP Leg 61	Czc Mzc Cret.	Strati	De Wever P. 1981d
World	Mzc		Premoli-Silva I. *et al.* 1976

Cenozoic radiolaria from European Platform: a review

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ABSTRACT
Stratigraphic correlations between western and eastern European areas under a clear boreal influence are difficult because different paleogeographic domains (boreal *vs* tropical) are involved in eastern countries and most of the boreal data which were acquired in eastern countries used technical equipment and methodologies which are not the same as in western countries, and also the Russian literature is not easily accessible, is usually in cyrillic and frequently lacks good illustrations.
From a review of Cenozoic Peri-Tethyan radiolarian investigations, it has become clear that there are problems with respect to correlate western and Russian studies, namely: Russian geographical and geological terminology, which is difficult for foreign scientists to understand; differing approaches to the establishment of a biozonation and hence to correlations; and species determination (and systematics) which were made, in some cases, on the basis of thin sections, or badly preserved fauna. In this article we give an explanation of some Russian geographical and geological terms. Information about the age, precise locality (with latitude and longitude) of Cenozoic deposits discovered in sections and wells of the Peri-Tethys basin along with a brief lithology, stratigraphy and biostratigraphy, based on micro and macrofauna investigations, for different regions, is presented in tabular form. And all palaeoenvironmental information is shown on the maps. The goal of this paper is to correlate various biological timescales from western to easternmost Europe with emphasis on data collection from eastern Europe.

KEY WORDS
radiolarians,
Peri-Tethys,
Cenozoic,
silica,
review.

Stratigraphic correlation of Upper Palaeozoic through Recent high latitude rocks has been hampered by a lack of world-wide cooperative studies. Now that scientific exchange is easier between Eastern and Western workers, a rapid solution of many stratigraphic problems may be achieved through joint projects. Before starting on this detailed comparison of eastern and western studies we here present a review of previous works.

RÉSUMÉ

Les corrélations stratigraphiques entre les régions d'Europe occidentale et orientale sous influence boréale franche sont difficiles car différents domaines paléogéographiques (boréal *vs* tropical) sont généralement intriqués dans les pays de l'Est et la plupart des données boréales acquises dans les pays de l'Est le furent avec des moyens techniques et des méthodes différents de ceux des pays occidentaux, en outre la littérature russe n'est pas aisément accessible, est écrite en caractères cyrilliques et manque généralement d'illustrations de qualité.

À partir d'une revue des travaux effectués sur les radiolaires cénozoïques de la Péri-Téthys, il est devenu évident que des problèmes majeurs de corrélations se posaient pour plusieurs raisons. Tout d'abord à cause d'aspects géographiques et terminologiques qui sont parfois difficiles à appréhender pour des scientifiques étrangers. Ensuite parce que les approches diffèrent dans l'établissement des biozonations et des corrélations. Les acceptions varient aussi pour les déterminations spécifiques (et donc aussi systématiques) qui furent d'ailleurs effectuées, dans de nombreux cas, à partir de plaques minces, ou de faunes mal conservées. Dans le présent article nous donnons une explication de quelques noms géographiques ou termes géologiques. Nous présentons aussi sous forme de tableaux et de cartes des informations à propos des âges, précisons les localisations (en latitude et longitude) de dépôts Cénozoïques trouvés sur des coupes ou en forage et appartenant aux bassins Péri-Téthysiens, accompagnés d'une brève description lithologique, du cadre stratigraphique et paléoenvironnemental, fondés sur les micro- et macrofaunes, pour les différentes régions. L'objectif de cet article est de pouvoir corréler diverses échelles biologiques d'Europe occidentale avec les plus orientales en mettant l'accent sur les données d'Europe orientale.

Les corrélations stratigraphiques du Paléozoïque Supérieur au Récent dans les roches de hautes paléolatitudes ont été freinées par un manque de coopération largement internationale. Maintenant que les échanges scientifiques sont plus faciles entre pays de l'Est et de l'Ouest, une solution à divers problèmes stratigraphiques devrait pouvoir être obtenue rapidement par des projets conjoints. Avant de commencer cette étude détaillée entre stratigraphies occidentale et orientale, nous présentons une revue des travaux antérieurs.

MOTS CLÉS
radiolaires,
Péri-Téthys,
Cénozoïque,
silice,
revue.

INTRODUCTION

For both the upstream and downstream side of several studies it is necessary to homogenize different biological chronometers. The goal of this paper is to consolidate information so that geologists interested in basinal deposits can quickly and easily use the interrelationship of microfossils as a useful tool. Our goal is to correlate, using modern methods, various biological timescales from western to easternmost Europe with emphasis on data collection from Eastern Europe.

Most studies in micropalaeontology in the former Soviet Union developed without the knowledge of the western literature and, to some extent, the reverse was also the case which arose a problem of consanguinity.

Some fossil groups have been studied for a long time and are relatively well known. Correlation between several basins using these fossil groups is possible, even though still imperfect. Planktic organisms have been shown to be more useful than benthics. On the contrary, some other groups, such as radiolarians, have been largely ignored.
Microfossils are important, but some groups are often overlooked as **stratigraphic tools**. Their usefulness for quick analysis in Palaeozoic to Eocene rocks is excellent if certain systematic conformity can be agreed upon. The changing relationships between microfossils groups (diatoms, foraminifers, radiolarians, conodonts, sponge spicules, and nannofossils) may signal changes in basin and oceanographic conditions.
Stratigraphic correlations with eastern European areas under a clear boreal influence are difficult because: (1) different paleogeographic domains (boreal *vs* tropical) are involved; (2) most of the boreal data has been acquired in eastern countries where technical equipment and used methodologies are not the same as in western countries (use of a scanning electron microscope is still uncommon in several countries); (3) the Russian literature is not easily accessible, is usually in cyrillic and frequently lacks good illustrations.
The long term objective of our study is to:
1. Re-examine the taxonomy of radiolarians from western intracratonic basins and from the Russian Platform, Caspian Sea Region, Siberian Lowlands, North Kazakhstan.
2. Set up a biostratigraphy of these organisms (quantitative biochronology) with the same means as that used for the recent Tethyan synthesis (Baumgartner *et al.* 1995).
The present paper represents the first part of this final objective.

From a review of Cenozoic Peri-Tethyan radiolarian investigations, it has become clear that there are problems with respect to correlate western and Russian studies, namely: (1) Russian geographical and geological terminology, which is difficult for foreign scientists to understand; (2) differing approaches to the establishment of a biozonation and hence to correlations; (3) species determination (and systematics) which were made, in some cases, on the basis of thin sections (Chediya 1973), or badly preserved fauna (Subbotina 1960). In this article we give an explanation of some Russian geographical and geological terms. Information about the age, precise locality (with latitude and longitude) of Cenozoic deposits discovered in sections and wells of the Peri-Tethys basin along with a brief lithology, stratigraphy and biostratigraphy, based on micro- and macrofauna investigations, for different regions, is presented in tabular form (Table 2) and all palaeoenvironmental information is shown on the maps (Figs 6-14).

Future studies will provide:
– Lithologic descriptions of some key sections and cores that are representative of some regions or basins with their precise locations (latitude and longitude).
– Microfossil database. A complete computerized database (with taxonomy, photos, geographic occurrences, etc.) is being developed.

Other indirect benefits:
– Opportunity to develop closer relationships between scientists and to have easier access to local literature.
– Understand terminologies in translation such as those referring to lithologies (domanikoids facies, opoka, aleurolites, menilites) or geography (Preduralie *vs* Cis-Ural, Zauralie *vs* Trans-Ural, Predmugodzharie *vs* Cis-Mudjarie, Pri- = nearby, ex. Pripolar...)

Stratigraphic correlation of Upper Palaeozoic through Recent high latitude rocks has been hampered by a lack of world-wide cooperative studies. The reasons include a global political climate that hampered technology transfer between countries and scientists. Now that scientific exchange is easier between Eastern and Western workers, a rapid solution of many stratigraphic problems may be achieved through joint pro-

jects. Sample and technology exchange will help researchers to see a more complete fossil record and better networking can now allow interested workers to develop models that will help to interpret geologic basins. Before starting on this detailed comparison of eastern and western studies we will present a review of previous works.

HISTORY OF STUDY ON RADIOLARIANS

A good review of this topic has been published by Sanfilippo *et al.* (1985a). Parts of it are quoted in the present text.

For a long time (and one can still find it in some handbooks) radiolarians have been regarded as being of little use for stratigraphy. For example, Shrock & Twenhofel (1953: 67) indicated that "fossil Radiolaria ... have not been found useful for age determination or correlation, partly because of the fact that fossil species are much like existing ones, and partly because so few forms have been found." More recently one can find: "*Ce sont de mauvais fossiles ayant peu varié depuis le Primaire jusqu'à l'Actuel*" (Encyclopedia Universalis 1980: 1065b). This reveals how *idées reçues* have longevity.

In 1950, the reasons for considering radiolarians to be useless as a stratigraphic tool seemed obvious. All the literature of the previous years supported the idea that the families and genera of radiolarians in Palaeozoic rocks are the same as those in present-day plankton (Campbell 1954). Even at the level of species, many forms in "Recent" sediments collected from the ocean floor by the *Challenger* expedition were seen to be the same as those occurring in Early Tertiary sediments on Barbados (Haeckel 1887). A chalk from the island of Rotti, near Timor, dated as Pliocene, contained a radiolarian assemblage showing greater similarities to Mesozoic faunas of Europe than to Late Tertiary assemblages and present-day plankton (Tan 1927, 1931).

Pessimism concerning the inutility of radiolarians for stratigraphic purposes was erradicated by the work of Riedel (1952, 1953). Material obtained from oceanographic cruises, such as the Swedish *Deep-Sea* Expedition of 1947-1948, provided the key to understand the utility of radiolarians for stratigraphy. The lower parts of several piston cores from the tropical Pacific were found to contain radiolarian assemblages similar to those that had been described from the Early Tertiary of Barbados, or the Late Tertiary of Italy and California. The radiolarian assemblages of the upper parts of all the cores in the region contained a constant component, comprising species described from present-day plankton, and many contained as well a part that varied from core to core, but could be matched with one or more of the Tertiary assemblages that had been encountered a few metres below the sediment surface. Evidently, the rates of accumulation of pelagic sediments were sufficiently low, and physical disturbances of bottom sediments were sufficiently common and intense, to cause widespread admixture of Tertiary radiolarians with Recent ones at the sediment surface (Riedel 1952, 1957a). Therein lays the explanation for the large number of species in common between recent assemblages, and those in Tertiary rocks. In fact the radiolarians at different levels in the Tertiary were sufficiently different to permit their application in biostratigraphy. Therefore, the "Mesozoic aspect" of the "Pliocene" assemblage from Rotti became increasingly odd. Re-examination by Riedel of the samples involved led to the solution: the *Dutch* expedition had collected samples of pelagic chalks of two different ages. The samples containing the rich radiolarian assemblages can be dated as Cretaceous on the basis of their calcareous nannofossils, and the samples containing Pliocene nannofossils have a sparse radiolarian fauna that had not been noticed before.

The development of the knowledge of stratigraphic utility of radiolarians has been recent and rapid. Now there are about a hundred paleontologists (academic and industrial) whose principal involvement is radiolarian stratigraphy.

Initial studies of radiolarian biostratigraphy were established generally on similarity at the level of species, and did not contradict the fixed conviction that most genera and families had persisted from the Palaeozoic to the Recent. However, with the Deep Sea Drilling Project, which has been coring long columns of pelagic sediments in all major oceans since 1968, a better knowledge of stratigraphic ranges of radiolarian species was

obtained, and as ancesror-descendant relations were demonsttated, it became obvious that the lengthy stratigraphic ranges of genera were unnatural.

FROM PLANKTON TO SEDIMENTARY ROCKS

Radiolarians, a class of actinopods, are marine protozoa with a capsulat membrane which separates an ectoplasm from an endoplasm. Polycystines (a Supetorder), with theit siliceous skeletons, are the only radiolatians *s.l.* which are preserved as fossils. At present, among Polycystines, members of rhe order Nassellatia are the most diversified, but Spumellarians seem to be the most abundant (Lombari & Bowden 1982). The skeleton is included within the cytoplasm, out of contact with sea water and, therefore, is not exposed to dissolution during the cell's life. Several groups have a high content of endoplasmic oil-droplets and could represent a primary source of hydrocarbons.
Radiolarians may exist from the poles to the equator, but their abundance varies. Like other planktonic organisms, rheir abundance is more dependent upon the supply of nutrients than on the silica supply. Most of them live in the upper few hundred metres of the water column in all oceans and seas of normal marine salinity. Their diversity and numbers of individuals decline in near-shore watets. In high latitudes the number of species (divetsity) is much smallet than in low latitudes, even if the number of specimen (abundance) is high. A latitudinal distribution does exist for radiolarian associarions. It is also possible to differentiate surface from subsurface assemblages.

After death, an individual test is at least partially dissolved during settling and while it lies exposed on the bottom of the ocean. According to Schrader (1971), Dunbar & Berger (1981), Asper *et al.* (1992), the settlement of microplankton occurs in faecal pellets. But there were not much radiolatians records which have been find in them but around rhem (Nakaseko *et al.* 1985). Chemical and physical characteristics of tests vary accotding to taxa (King 1975, 1977) as does the dissolution affecting them (Riedel 1958; Renz 1976; Bjørklund & Goll 1986; Swanberg & Bjørklund 1992). Because of the ubiquity of radiolarians in plankton, and the fact that the presetvation of theit skeletons is not conttolled by a compensation depth analogous to that for calcium carbonate, one might expect to find them more commonly in present-day and ancient sediments, than is actually the case.

The numbers of individuals and species ate lower in sediment (and *a fortiori* in the rock) than in plankton. Radiolarians may be abundant in relatively shallow basins close to a shoreline, *e.g.* the Santa Batbara Basin, off California under a depth of 500 m (Kling 1979) and the Norwegian fjords (Swanberg & Bjøtklund 1992). In all these regions, tadiolatians ate accompanied by (and in the polar regions markedly dominated by) diatoms. If, at certain localiries in these regions, radiolarians are not a prominent component of the sediments, it is usually a result of their dilution by othet constituents, and not of their dissolution.

In oceanic recent sediments (Miocene-Present), the radiolarian abundance on a site is connected either to high or low stands (*e.g.* South Atlantic coast off Africa, Walvis Ridge; Diester-Haass *et al.* 1992; Hay & Brock 1992).
Less than 1% of the silica fixed by planktonic organisms in surface waters is preserved within the geological record. Silica phase transformations are accompanied by porosity reduction. The otiginal porosity is higher when the sediment is richer in silica and during diagenesis (Isaacs 1981). For the geologist, the porosity decrease (volume) corresponds to a diminishing of the thickness and he has to rake into account the important decompacring factor when making accumularion rate and palaeoproductivity calculations (De Wever *et al.* 1994).
In addition to pressure and temperature, time favours both opal transformations. Thus cherts are more prevalent in older sediments (Palaeozoic and Mesozoic) and porcelanites in more recent ones (Cenozoic). The transformation opal-A to opal-CT is estimated to occur at 25-50° and

takes 20 Ma in areas of low to moderate sedimentation rates and 5-10 Ma in areas of high sedimentation rates (Kastner 1981). The opal-CT to quartz transformation occurs within 40-50 Ma (Keene 1976).

STRATIGRAPHY

Because of the difficulty to extract radiolarians from siliceous rocks, the first zonations were proposed for the Cenozoic only during the late 1970's.

Some of the most fundamental step, that of recording the earliest or latest occurrence of a radiolarian taxon in a series of samples, is often complicated enough to constrain a part of subjective opinion. This applies to the limits of species defined morphotypically. Morphotypic limits are perforce used when phylogenetic relationships are unknown, and may also be used in addition to evolutionary limits, when lines of evolution are clear. Under some circumstances, evolutionary limits can be stratigraphically more useful than morphotypic ones. Such is the case when all members of a species change gradually to the descendant morphology, as in the species belonging to the genus *Diartus* (*D. pettersoni*, *D. hughesi*) or *Spongaster* (*S. tetras*, *S. pentas*, *S. berminghami*) (Johnson & Nigrini 1985a, b). That matter is complicated in some cases when an ancestral form persists to co-occur with a descendant lineage over some length of time (as *Pterocorys sabae* and *P. campanula* persist along with their ancestor *P. clausus* Caulet *et* Nigrini, 1988; or as *Clathrocyclas bicornis* persists along with its descendants *Cycladophora sphaerica* Popova, 1991 and *Cycladophora hayesi* Lazarus, 1988). These methods produce a list of stratigraphic events in each sequence, and the different succession of events are correlated. In most cases some of the correlation lines cross and it is necessary to choose which of the two conflicting pieces of evidence (crossing lines) is to be accepted. For this purpose, it is helpful to evaluate the level of reliability of each event, according to a number of criteria. It is worth noting that a diachronism must be invoked in some cases. This diachronism has been demonstrated between different oceans (Indian/Pacific), in the same ocean (western/eastern Indian and Pacific Oceans), as well as for a same phylogenetic transition (Johnson & Nigrini 1985a, b). In some cases this diachroneity reaches up to 10 Ma: as for *Acrosphaera murrayi* gr., or *Lithostrobus* cf. *L. hexagonalis* (Nigrini & Caulet 1992). In some special environments, such as upwelling systems, this diachroneity may be considerable: *Lamprocyclas hadros* appears more than 10 Ma ago off Oman, while it first occured at 6 Ma off Peru (Nigrini & Caulet 1992).

A succession of specific events provides the greatest stratigraphic resolution, but it is awkward to transmit information in this form to biostratigraphers working with other fossil groups, and particularly to general geologists. The message is simplified by separating the succession of events into clusters, each of which delimits a zone. Events used to define zones are usually selected on the basis of their existence reliably identifiable over wide geographic areas. Some specialists of several microfossil groups describe as many zones as are permitted by the number of events available to them. Such a procedure would be unrealistic for radiolarians, especially in the high-diversity areas of the tropical and temperate latitudes, and therefore only a practical number of radiolarian zones are defined there (ex. about thirty for the entire Cenozoic by Sanfilippo *et al.* 1985a).

Ongoing work, especially on material acquired during the Deep Sea Drilling Project and Ocean Drilling Program, provides a growing number of radiolarian events, and of sequences in which they are recognized. It has thus become impossible for any individual researcher to organize all of the results for determining what is the most likely stratigraphic order of events in each biogeographic province, and which variation requires interpretation in terms of environment, preservation, factors etc. To facilitate this task, one may use the method of probabilistic stratigraphy described by Hay (1972). The method involves an initial arrangement of the events in a best estimated stratigraphic order, and then inverting the above/below relations of pairs of adjacent events until the number of contradictions is the minimum. A major objection to this

AGE	Stage	Moderate deep water facies: Regional plaktonic foraminiferal zones	Shallow water facies: Nikitina 1972 (Foraminifera)	Shallow water facies: Over zones (Foraminifera)	Shallow water facies: Zagorodnuk 1967 (Radiolaria)	Shallow water facies: Characteristic and concomitant species: Foraminifera	Shallow water facies: Characteristic and concomitant species: Radiolaria
EOCENE	Al'minsky	*Bolivina antegressa* s.s	*Bolivina antegressa* *Lenticulina calcariformis*	*Lenticulina limbosa*	*Cenosphaera mariae*	*Cylindroclavulina rudilosta, Lenticulina simferopolica, Marginulina behmi, Brotzenella taurica taurica, B. praebinaensis crassa, Daniella neogranosa, Nonion curvisepta, Caucasina aziderensis*	*Cenosphaera mariae, Porodiscus turgaicus, Druppatractus santaennae, Cenosphaera mitgarzae, Spongodiscus concentricus, Cagnosphaera valentinae, Phacodiscus tumefactus, Thecosphaera scabra, Sethocyrtis minimus, Astrophacus n.sp.*
			Bolivina jacksonensis *Brozenella taurica taurica*			*Cyclammina pseudocancellata, Pseudoclavulina colomi, Marginylina intracompressa, Brotzenella taurica acutiformis, Uvigerina eocaena*	
	Bodraksky	*Globigeraspis tropicalis*	*Brozenalla taurica acutiformis*	*Lenticulina miera*	*Spongasteriscus gorskii*	*Marginulinopsis fragarius, Plectofrondicularis sturiata, Bolivina jacksonensis, Bulimina sculptilis*	*Carposphaera usuriensis, Stylodycha tschjebkoi, Sethopyramis victori, Amphistylus ensiger, Theconis humilis, Spongastericus gorskii*
		Globigerina turcmenica	*Spiroplectammina vicina morpha*		*Xiphatracus visendus*	*Haplophragmoides macer, Caucasina eocaenica*	*Xiphatracus visendus, Carposphaera usuensis, Sethopyramis victori, Spongastericus gorskii, Stylotrochus radiatus, Sethocyrtis parvissimus, Porodiscus annularius*
		Hantcenina alabamensis	*Brozenella kerestensis* *Pseudoclavulina subbotinae*	*Lenticulina dimorpha*	*Astrophacus duplus*: *Phacodiscus duplus*	*Lenticulina grodnensis, Anomalinoides postvulgaris, Brotzenella kerestenensis*	*Phacodiscus duplus, Conocaryomma aralensis, Astrophacus duplus, A. tastatus, Phacodiscus subsphaeriscus, Prunopyle ovata*
		Acarinina rotundimarginata	*Lenticulina kuberlina*		*Astrophacus duplus*: *Phacodiscus* sp.	*Hopkinsina bykovae, Eponides stellatus, Gemellides kasanstanicus, Pseudoclavulina listerelloides, Hantkennina liebusi, Bulimina praesculptilis*	*Astrophacus duplus, Phacodiscus subsphaeriscus, Conocaryomma aralensis, Lithomelissa n.sp., Rodesphaera n.sp., Sethocyrtis tamdiensis n.ssp.*
	Simferopolsky	*Acarinina bulbrooki*	*Brozenella postacuta aksuatica*	*Lenticulina subspanilosa* *S. carinatiformis*	*Podocyrtis prunoformis*	*Textularia tjuljuscica, Lenticulina ax.gr. inornata, Truncorotalia aragonensis caucasica*	*Lychnocanium bellum, Carposphaera megapora n.ssp., Stylosphaera minima, Spongodiscus aralensis, Podocyrtis prunoformis, Lithatractus turgaicus*
		Truncorotalia aragonensis	*Anomalina scrobiculata*		*Cenosphaera pila*	*Ammobaculites midwayensis, Lenticulina ergenica, Acarinina pentacamerata, Hopkinsina compacta, Bulimina mitgarziana, Brotzenella postacuta postacuta*	*Cenosphaera pila, Carposphaera microporulosa, Thecosphaera n.sp., Cromyodruppa tabesensis, Ellipsostylus inclaris, Amphibrachium gracilis, A. planum, Amphicaridiscus fusoides, Histiastrum palaogenus, Stathostylus acutus*
	Bakhchisaraisky	*Globorotalia subbotinae*	*Lenticulina mexicana nudicostata*	*S. terena* *B. postacuta postacuta*	*Amphicarydiscus fusoides*	*Marginulina eofragarius, Lenticulina vialovi*	
		Globorotalia aequa	*Lenticulina mexicana praemexicana*			*Gratus lybicus, Cidicidoides textilis, Gaudryina navarroana*	

FIG. 1. — Correlation between regional zones based on planktonic foraminifers and radiolarian zones on Russian platform (according to Zagorodnyuk 1969).

method is that no plan exists for taking into account the disparity of reliability, between recorded data; state of preservation, type of bioevent, geographic extension of an event...

Differing from oceanic data, land-based collections of data are frequently isolated, scattered stratigraphically and geographically and the difficulty there lays in establishing correlation between events in spaced sequences. When information is scarce and scarce to such a point that correlation is impossible or at least delicate, such as in the Mesozoic, some workers use another method desctibed as Unitary Associations (Guex 1987, 1991).

Diachroneity is one of the primary factors limiting biostratigraphic correlations. Independent regional calibration of biostratigraphic event thus offers the possibility of significantly improved age models. Regional calibration of zonations is also needed for biostratigraphic events that are endemic to the tegion. It has long been recognized that radiolarian biogeography, perhaps more than any other microfossil group, differs between low and high latitudes, with many endemic species occurring within the latitudinally arranged biogeographic provinces of the ocean. Radiolarian stratigraphy in the Cenozoic reflects this distinctive biogeographic pattern, with separate zonation schemes for the tropics (Sanfilippo *et al.* 1985a; Johnson *et al.* 1987), Antarctic (Caulet 1991; Lazarus 1992) and Norwegian-Greenland sea (Goll & Bjørklund 1989).

SUMMARY OF STUDIES

The most abundant and used data have been obtained from the oceans. In order to position land-based studies relative to oceanic ones we will begin with a short summary of oceanic studies contributing to our understanding of radiolarian occurrences through the Cenozoic. The most important source of information on the occurrences and distribution of Cenozoic radiolarians is the series of Initial Reports of the Deep Sea Drilling Project and Ocean Drilling Program.

A compilation of papers in that series, dealing with Cenozoic radiolarians is provided by Premoli Silva *et al.* (1976), for Legs 1-39, by Sanfilippo *et al.* (1985a) for subsequent legs, and more recently by Spencer-Cervato *et al.* (1993) for the North Pacific Ocean.

ACQUISITIONS FROM OCEANS

Most of the recent studies on Cenozoic radiolarian stratigraphy have been on samples from tropical and temperate latitudes, but the first radiolarian zones were defined from the Antarctic (Hays 1965). High-latitude radiolarian assemblages contain only 10% of the number of species found in low-latitudes assemblages, and their most obvious constituents are species that are absent or rare in low latitudes. This implies that radiolarian zonation established for high latitudes differ from that applied in low latitudes. Progress to solve this problem are expected from investigation of mid-latitude "sub-boreal" samples which contain elements of both cool- and warm-water assemblages, and particularly from regions such as the southern Russian platform.

Late Miocene - Recent

Neogene radiolarian sediments have been reported off north-west Africa, California and Central America (Lancelot, Seibold *et al.* 1978; von Rad, Ryan *et al.* 1979; Lancelot, Winterer *et al.* 1980; Rosendahl, Hekinian *et al.* 1980; Yeats, Haq *et al.* 1981; Watkins, Moore *et al.* 1982...).

In Recent sediments Goll (1976a) has shown that radiolarians are widespread in the Pacific and Indian Oceans (except beneath the central water masses), and are restricted to high southern and northern latitudes, and off West Africa in the Atlantic Ocean. The biogeographic distribution of distinct assemblages throughout the Pacific and Indian Oceans is described by Sancetta (1978), and for the Pacific by Casey (1971a, b) and by Moore (1978). More restricted biogeographic investigations of the tropical Pacific have been published by Nigrini (1968) and by Johnson & Knoll (1974), and North Pacific distributions are described by Nigrini (1970), Sachs (1973) and Kruglikova (1977). Studies of radiolarians from particular regions are listed on table 1.

In addition to numerous contributions of the Deep Sea Drilling Project, the stratigraphy of late

Neogene radiolarians in the tropical Pacific is described by several authors (Table 1).
The distribution of radiolarian sediments in the Indian Ocean is considered in some detail by Caulet (1978, 1991) and Nigrini (1991). Biogeographic investigations have been made in the Indian Ocean sector of the Antarctic by Petrushevskaya (1967), and in lower latitudes by Nigrini (1967), Petrushevskaya (1972a, b), Johnson & Nigrini (1980, 1982) and Johnson *et al.* (1987). Late Neogene Indian Ocean radiolarian stratigraphy in high latitudes has been described by Hays (1965) and Keany (1979), and in lower latitudes by Caulet (1979).
The general distribution of Recent radiolarian sediments in the Atlantic Ocean is described by Goll & Bjørklund (1971(2), 1974). Biogeographic investigations have been made for the South Atlantic (Morley 1979), the eastern tropical Atlantic (Labracherie 1978, 1980a, b), the Gulf of Mexico (Casey *et al.* 1979a, b, c), the North Atlantic (Petrushevskaya 1969), and the Norwegian-Greenland Sea (Bjørklund 1973; Petrushevskaya & Bjørklund 1974). Stratigraphies based on selected taxa have been published for the Miocene-Pliocene of the Norwegian-Greenland Sea by Goll & Bjørklund (1980), and for the Quaternary of the central North Atlantic by Morley & Hays (1979b). Radiolarians from Recent sediments in the western Mediterranean are described by Caulet (1974).

Oligocene - Middle Miocene
Deep Sea Drilling Project cores show that the Middle Tertiary distribution of radiolarian sediments is similar to that of the Late Tertiary, except that fewer of these older sequences in the Indian Ocean contain siliceous microfossils, and their distribution in the eastern Pacific is limited as a result of sea-floor spreading. In the Caribbean region, middle Tertiary sediments frequently contain radiolarians, but they are not present in younger sediments. On the other hand, in the northern Pacific, siliceous microfossils are more prevalent in late than in middle Tertiary sediments. Theyer & Hammond (1974a, b) correlate radiolarian biostratigraphy with magnetic stratigraphy in tropical Pacific cores, and Johnson & Parker (1972) correlate radiolarian and foraminiferal stratigraphies while Sanfilippo & Nigrini (1995) correlate radiolarians, nannofossils and foraminifers in the Pacific, Atlantic and Indian Oceans for the Oligocene-Miocene transition.

Eocene
In deep-sea sequences, Eocene radiolarians occur in the central and western tropical Pacific, the Tasman Sea, scattered patches in the low and middle latitudes of the Indian Ocean, the western Atlantic from the vicinity of the Rio Grande Rise through the Caribbean to Nova Scotia, and in the eastern Atlantic from north-west Africa to the Norwegian-Greenland Sea (Bjørklund & Kellog 1972; Bjørklund 1976a, b; Bjørklund & Goll 1986; Lancelot, Seibold *et al.* (1978); Montadert, Roberts *et al.* 1979; Sanfilippo & Riedel 1979; Tucholke, Vogt *et al.* 1979; von Rad, Ryan *et al.* 1979; Weaver 1976). Sancetta (1979) has described the biogeography of assemblages in the Pacific and Indian Oceans from Eocene to Miocene and Abelmann (1990) those for the Antarctic.

Palaeocene
Radiolarian occurrences of this age are very few. They were encountered by the Deep Sea Drilling Project at isolated sites off eastern America, off Spain and North Africa, in the Tasman Sea, and scattered through the Indian Ocean. In north-west Atlantic Palaeocene occurrences are recorded by several Deep Sea Drilling Project Legs.

ACQUISITIONS FROM LAND
Late Miocene - Recent
Ehrenberg published (1854, 1873, 1875) the results of his radiolarian investigations carried out on Barbados.
In western America, early reports of land-based occurrences of Miocene radiolarians include Campbell & Clark (1944) in California, Mertz (1966) in Peru, and Frenguelli (1941) in Chile. In Japan, one may note works published by Nakaseko (1960, 1963); and in the eastern part of the former USSR those by Kozlova (1960) from Sakhalin, and Runeva (1975) from Kamchatka. A land-based occurrence of Pliocene radiolarians is known from Rotti (Riedel 1953).

SCALE			NORTH EURASIA			OCEAN TROUGHS		
SERIES	SUBSERIES	Stage	FORAMINEFRAL ZONES (MSK 1981, Paleogene commission)	RADIOLARIAN ZONES AND LAYERS (R. Kh. Lipman)	NANNOPLANKTON ZONES (MSK 1981, Paleogene commission)	NP	CP	NANNOPLANKTON AND RADIOLARIAN ZONES (A. Sanfilippo, M.J. Westberg & W.R. Riedel 1981)
OLIGOCENE	UPPER	Chattian	*Speeroldia variabilis*	layers with Cenodiscidae		25 24	19	*Dorcadospyris ateuchus*
	MIDDLE	Rupelian	*Spiroplectammina carinata oligocenica*	unknown		23	18 17	*Theocyrtis tuberosa*
	LOWER	?	*Globigerina officinalis (Lenticulina herrmenni)*	*Cenosphaera almaensis* layers zone *Phacodiscus licharevi*	*Heliocoponthosphaera reticulata* *Coccolithus subdistichus*	22 21	16	
EOCENE	UPPER	Priabonian	*Bolivina enteregressa* *Globigerina tropicalis* *Globigerina turcmenica*	layers with Biosphaeridae *H. lentis, T. splendicus, S.tschujenkoi* zone *Ellipsoxiphus chabakovi*	*Discoaster barbadensis*: *Istmolithus recurvus*; layers with *Sphenolithus pseudoradians* *Chiamolithus osmaruensis*	19/20 18	15	*Thyrsocyrtis bromia*
		?	*Hentkenina alabamensis* *Acarinina rotundimarginata*	zone *Conocaryomma aralensis*	*Reticulofenestra umbilica* *Nannotetrina fulgens*	17 16 15	14	*Podocyrtis goetheana* *Podocyrtis chalara* *Podocyrtis mitra*
	MIDDLE	Lutetian	*Acarinina bulbrooki*	zone *Spongurus biconstricus* *Amphycaridiscus fusoides - Amphybrachium gracilis* zone	*Discoaster subblodoensis*: *Rhobdasphaera inflata* Lower subzone	14	13 12	*Podocyrtis ampla, Thyrsocyrtis triacantha* *Theocampe mongolfieri* *Theocotyle cryptocepla* *Phormocystis striata*
	LOWER	Yprian	*Globorotalia aragonensis* *Globorotalia subbotinae*	*Amphycaridiscus fusoides - Amphybrachium gracilis* zone layers with Spongodiscidae zone *Sedrodiscus vialovi* *Ellipsostylus triplarus*	*Discoaster lodoensis* *Marthosterites tribrachiatus* *Discoaster diastyptus* *Discoaster binodosus* *Marthosterites contortus*	13/12 11	11 10 9	*Phormocystis striata* *Buryella clinata* *Becoma bidartensis*
PALEOCENE	UPPER	Thanetian	*Acarinina susphaerica*	zone *Cromyodruppa regularia* *Porodiscus ornatus* zone *Cenosphaera caucasica*	*Discoaster multiradiatus* *Heliolithus*: *Heliolithus riedeli* *Discoaster gemmeus* *Discoaster kleinpelli*	10 9		*Heliolithus riedeli*
	LOWER	Montian	*Globorotalia conicontruncata* *Globorotalia angulata*	zone *Cenodiscus magnus, C. longus* zone *Cenosphaera irregularis*, *Canellipsis variabilis*; layers with Prunoidea	*Fasciculites tympaniformis* *Cricolacolithus tenuis* s.l. *Ellipsolithus macellus*			
		Danian	*Acarinina inconstans* *Globoconusa daubjergensis* *Globigerina taurica*	no zone no zone				

FIG. 2. — A correlation scheme of zonal division of Paleogene of northern Eurasia and oceanic troughs based on radiolarians, foraminifers and nannoplankton (Lipman 1993).

In Europe, Italian localities provide the majority of our information on Neogene assemblages of the Mediterranean region; summaries by Sanfilippo (1971) and Sanfilippo *et al.* (1973, 1985a) cover many of the mainland localities described by early Italian authors (Vinassa de Regni 1900; Carnevale 1908; Principi 1909; Anelli 1913; Lucchese 1927). In addition Sicilian Late Miocene and Pliocene occurrences have also been described since 1880 by Stöhr and since 1890 by Dreyer (see also Table 1). Calabrian occurrences of Pliocene and Quaternary assemblages are also reported by Seguenza (1880), Guerrera (1881), Pantanelli (1882). Paratethyan Miocene assemblages are described from Central Europe: Romania by Dumitrica (1968), the pre-Carpathians by Runeva (1969) and Austria by Bachmann, Papp & Strradner (1963).

Oligocene - Middle Miocene

Miocene radiolarians are known from Maryland in the eastern North America (Martin 1904). A summary of Caribbean occurrences has been compiled by Sanfilippo & Riedel (1976); particularly significant are the Middle Miocene of Trinidad, Jamaica and Barbados and the Oligocene of the Oceanic Formation on Barbados. Land-based middle Tertiary radiolarian occurrences are described by Takayanagi *et al.* (1976) in the Miocene of Japan, and Runeva (1975) in the Oligocene and Miocene of Kamchatka. An Early Miocene assemblage is recorded from the Andaman Islands (Indian Ocean) by Jacob & Shrivastava (1952).

In Europe, an early Oligocene locality is known in East Prussia (Eisenack 1954). Early Miocene sequences are known from southern Spain (Berggren *et al.* 1976) and northern Italy (Westberg, Sanfilippo & Riedel 1981). Paratethyan occurrences of Early Miocene are described by Barwicz-Piskorz (1978) and Dumitrica (1978).

Lipman (1972) and Kestner (1973a,b) describe Oligocene assemblages from the USSR.

Eocene

Land-based Eocene occurrences in America are recorded by Clark & Campbell (1942, 1945) from California, and by Cunningham (1895), for an occurrence in Mississippi. In the Caribbean region the classic occurrence of Barbados was described by Ehrenberg (1854, 1873, 1875) and Bütschli (1882a, b). An occurrence on Cuba was reported by Palmer (1934) and other localities on Barbados, Trinidad, Cuba, Grenada and Panama are summarized by Sanfilippo & Riedel (1976).

In New Guinea some records are cited by Crespin (1958), in Saipan by Riedel (1957b), and in Kamchatka by Runeva (1975).

In Europe an occurrence is reported in northern Germany by Brandt (1935) and in Israel by Reiss (1952).

In the former USSR, Eocene radiolarians have been recorded in numerous papers (see Table 1).

Palaeocene

In North America, a Palaeocene radiolarian occurrence is recorded in Missouri (Frizzell & Middour 1951), and one in California (Foreman 1968). Sanfilippo & Riedel (1976) recorded an occurrence in Cuba.

In the former USSR, Palaeocene radiolarians are reported by several authors (Table 2).

STUDIES ON RUSSIAN PLATFORM

In analyzing Russian literature we discovered many geographical terms like: *Pre-Caucasus*, *ZaUralie*, *Povolshe* and so on, which are unfamiliar to the western reader. Similarly in geological descriptions there are such terms as "*slot*", "*svita*", "*horizon*" and so on. Here we give an explanation of terms which are currently in use in Russia. For clarity we preserved the original names of the subdivisions (in brackets in the text).

GEOGRAPHICAL TERMINOLOGY

– *Chukotka* = Tchouktches = Chukchi.
– *Crimsky*: Crimea.
– *Pre Black Sea* region: territory 400-600 km to the north of the Black Sea, southern Ukraine.
– *Pre Carpathians*: Carpathian folded area and the territory 200-300 km to the east of the Carpathian mountains.
– *Pre-Caspian* (or *Pre-Aral*): the territory to the

north of the Caspian (or Aral) Sea, but in some publications it can be the territory to the east and to the west of Caspian (or Aral) Sea.
– *Pre-Caucasus*: the territory 100 km to the north of the Caucasus.
– *Povolshe* (= *Povolshie*): territory along the right and left banks of Volga river.
– *Predmugodzharie*: Cis-Moudjari.
– *Preduralie* = Pre-Ural = Cis-Ural = West Ural.
– *Priaralie*: western Aral Lake region.
– *Stepnoi Crimea*: middle part of Crimea peninsula, territory near Simferopol.
– *Zauralie* = ZaUralie: territory to the east of Ural mountains (= Trans-Ural).

GEOLOGICAL TERMINOLOGY
Lithology
– *Aleurolites* (or *aleurolite*): sedimentary silty-clay rocks, which contains about 45% very fine grains of sand and more than 55% clay.
– *Argillite*: metamorphosed (low degree) aleurolites.
– *Opoka*: Russian analog of cherts (diatomite, radiolarite type) with a high percentage (more than 70%) of organic silica.

Stratigraphy
(according to A. Zhamoida et al. 1970)
– *Otdel*: a unit of a common ("chronostratigraphic") scale, translated by the term Series (English).
– *Svita*: always translated by the term formation, although in a strict sense this term "formation" does not exactly coincide with its interpretation by many Russian authors, as formation means the basic subdivision of the category of lithostratigraphic units.
– *Horizon*: layet.
– *Pachka*: we translated it as a member and it means literally a member of some larger subdivision (formation).
– *Sloi* and *plast*: there is no clear distinction between the English terms bed and stratum, which incidentally is also the case with the Russian terms *sloi* and *plast*.

In the following part the text is arranged in (1) geographical order (from the West to the East) and (2) by the year of publication. The numbers in square brackets which follows a reference correspond to the numbers used on table 2 and on corresponding location maps.

PRE-BLACK SEA REGION
Pre-Carpathians
Information about Oligocene and Lower Miocene Radiolaria of the Pre-Carpathian area (Vorotyshche, Slonitsa and Tysmenitsa Rivers sections) can be found in papers written by Subbotina (1960, [40]) and Runeva (1969, [39]). In our opinion the assemblage described by Subbotina seems to be redeposited because the taxonomic composition of the radiolarian association discovered in Oligocene-Lower Miocene deposits of the Zagotsky series is unusual. The radiolarian association was found in exotic pieces of breccia. All illustrated specimens are very poorly preserved and the association contains some species of *Dictyomitra*. There is a note in the paper about redeposition of foraminifers especially in sandy strata. Runeva (1969, [39]) discusses this problem in her paper where she introduced the generic composition (only) of Lower Miocene radiolarian associations from the Vorotyshchensky series of the Pre-Carpathian area. The conclusion of the author concerning the Oligocene and Lower Miocene age of Radiolaria bearing deposits from the Vorotyshche, Slonitsa and Tysmenitsa Rivers is that the radiolarian complex is a result of erosion of Cretaceous and Eocene radiolarian bearing deposits and was transported with the transgression of these sediments from the east or south-east.
Lozynyak (1969, 1985, [26]) described Eocene and Oligocene radiolarian assemblages from the Maniavskaya series (Lower Eocene), Bachinskaya bed (Middle, Upper Eocene) and Menilitovaya series (Oligocene) of the Carpathian folded area.

South-western Ukraine
The history of Palaeogene radiolarian studies in the Ukraine begins with Gurov's publication in 1893 (Gorbunov 1971, [9]) where he mentioned the presence of *Haliomma* sp. in Kharkov rocks from the southern areas of Kharkov Province. Information about the existence of Palaeogene radiolarian associations in deposits from Kiev, Chernigov and Poltava Provinces (Koryokovka,

Kholm villages, Volynsk), the Odessa area, the Pre-Black Sea troughs, the Verino pole, and along the Lopanj, Uda, Severskii, Donets and Melovaya Rivers comes from the publications of Titkovsky (1901a), Uspenskaya (1930, 1950a), Kaptarenko-Chernousova (1936, 1948), Pechenkina (1964) (all references from Gorbunov 1971). The most complete data about Paleogene radiolarians of this region can be found in the Gorbunov's monography (1979).

Borisenko (1958, [2]), working in the Krasnodarsky region and Seversky, Abinsky and Psobaisky Districts, has described forty new taxa from a shallow water radiolarian assemblage of Palaeogene deposits of the Psecupskaya Formation (svita). Ten new taxa were described by her (Borisenko 1960b, [3]) from the Upper Palaeocene rocks of the Abasinskaya Formation (svita) of eastern Kuban. The Lower-Middle Eocene deposits of western Kuban (Psecups River, interflow of the Shebsha and Shibica Rivers) contain a shallow water radiolarian association discovered in the Zybzinskaya, Kutaisskaya and Kaluga Formations (svita) (Borisenko 1960a, [4]). The same territory has been studied by Krasheninnikov (1960, [15]) and he presented the description of forty-two new radiolarian taxa (two genera and forty-two species) from Lower, Middle and Upper Eocene deposits from the western Pre-Caucasus (Moldavano-Psifsk and Zybzinsk area). The associations of radiolarians were found together with foraminifers belonging to the *Globorotalia subbotinae* and *Globorotalia aragonensis* Zones. The first radiolarian assemblage from the Zybsinsk series indicates shallow water conditions and the second one, from the Kuraissk series, deep water conditions.

Crimea Peninsula

A Late Palaeocene radiolarian association from the Kachinskaya layer (horizon), an Early Eocene associarion from Simferopolsky and a Late Eocene association from Bodraksky layer (horizon) of Crimea have been studied by Chedyia (1973 [6], 1981 [8]). The investigator concluded that: (1) there is no correlation between the radiolarian association from Stepnoi and southern Crimea; (2) the Palaeogene assemblages of Radiolaria from Crimea can not be correlated with the same from Middle Asia using normal correlation techniques based on the taxonomic composition of assemblages; (3) the assemblage can be correlated only by cycles of sedimentation. Correlation with Foraminifers showed that the radiolarian association from the Kachinsky horizon occurs with the *Acarinia acarinata* assemblage, the association from Bakhchisaraisky layer (horizon) occurs with the *Operculina semiurvoluta* assemblage, and the association from the Alminsky layer (horizon) with the *Globigerapsis index* assemblage.

Lipman (1982, [22]), working with the deposits of the Rubanovskaya formation in the Lower Serogorsky region of the Khersonsky district, has investigated Oligocene Radiolaria from the northern Pre-Black Sea area and Crimea. She introduced two new radiolarian taxa. The age of the shallow water radiolarian association was confirmed, using foraminifers and molluscs. The results of an investigation carried out by Lipman on Radiolaria from eight sections of Palaeogene deposits in the Bakhcnisaraisky district were published in 1984a [23]. She discovered associations of Radiolaria in outcrops of Upper Palaeocene to Lower Oligocene deposits from the Kasha River and Suvly-Kaya Mountain (Upper Palaeocene), the Belbek River (Lower Eocene), the Alma River (Middle-Upper Eocene) and Kizil-Djar Mountain (Upper Eocene-Lower Oligocene). All assemblages of Radiolaria occur together with foraminiferal zonal associations: *Acarinina subsphaerica*, *Globorotalia subbotinae*, *Hantkenina alabamensis*, *Globigerapsis tropicalis*, *Bolivina antegressa* and *Lenticulina hermanni*. In a second paper published by Lipman (1984b, [24]) correlation of zonal stratigraphical schemes, based on radiolarian and foraminifers, from the Palaeocene and Eocene deposits of the Pre-Caucasian and Apsheron peninsulae was introduced. The investigator applied her own zonal subdivision, based on radiolarian data for the Cherkessky key-section of the Pre-Caucasus and made a correlation between zonal radiolarian associations and assemblages described by Borisenko (1960a, [4]) and Krasheninnikov (1960, [15]) for western Kuban and by Mamedov (1970, [30]; 1973b, [32]) for the Apsheronian peninsula.

		North-Caspian Area	Don River	Middle Volga Area	East Ural Slope	West Siberian
EOCENE	UPPER	*T. andriashevi*	*T. andriashevi*			
	MIDDLE	*E. polysiphonia*	*E. polysiphonia*			
		C. alta	*C. alta*			
		H. quadratus	*H. quadratus*			
		L. separatum	*L. separatum*	*L. separatum ?*		
		H. hexasteriscus	*H. hexasteriscus*	*H. hexasteriscus*	*H. hexasteriscus*	
	LOWER	*H. lentis*	*H. lentis*	*H. lentis*	*H. lentis*	*H. lentis*
		S. paciferus			*S. paciferus*	
		P. fiscella		*P. fiscella*	*P. fiscella*	*P. fiscella*
PALEOCENE	UPPER	*Ph. cubensis*	*P. foveolata*	*P. foveolata*	*P. foveolata*	*P. foveolata*
			T. sengilensis	*T. sengilensis*	*T. sengilensis*	
		B. tetradica		*B. tetradica*		
		T. larnacium				
	LOWER			*B. alifera*	*B. alifera*	*B. alifera*

FIG. 3. — Correlation of radiolarian zones among North Caspian, Don River, Middle Volga, East Ural and West Siberian areas (from Kozlava 1993).

RUSSIAN PLATFORM

Upper Palaeocene and Lower to Upper Eocene radiolarian bearing deposits from the Voronesh anticline have been studied by Tochilina (1969, [41]; 1975). Radiolaria were not found in Oligocene deposirs from that region. The shallow water radiolarian associations occur together with foraminifers and molluscs. Three faunal periods closely connected with transgressions and regressions are established in this paper:

1. Late Palaeocene (Veshenskaya formation [*svita*]) - Early Eocene (Sheptukhovskaya formation [svita]);

2. Late Eocene (Tishkinskaya formation [*svita*]);

3. Late Eocene (Kasianovskaya formation [*svita*]).

The author compared faunal associations in deposits of the Voronesh anticline (Russian Platform) with that of the Pre-Caucasian and eastern slope of the Ural mountains and found many common species.

The southern part of Russian Platform has been studied by Zagorodnyuk (1969, [43]; 1975, [44]; 1981, [45]). She also investigated Radiolaria from the Asovo-Kubansk trough, Salo-Manyhsk interflow and the basin of the northern Emba (Pre-Caspian lowland). She recognized three different radiolarian associations for the Lower flow of the Don River and four assemblages in the Pre-Caspian lowland. Investigating the transition between some representatives of

Amphibrachium and *Histiastrum* she found out that: (1) apparently they have a common ancestor; and (2) preservation of the shells improves to the north.

The Lower Don basin and northern Pre-Caspian Eocene deposits served as a basis for Nikitina and Zagorodnyuk's (1981, [37]) study in which they carried out a correlative analysis of foraminiferal and radiolarian distribution within these rocks. The authors give a correlation between regional zones based on planktonic foraminifers and radiolarian zones, proposed by Zagorodnyuk (1967) for shallow water associations.

The scheme proposed in this paper does not correlate with the zonal subdivision based on Radiolaria data established by Lipman (1972, [20]; 1993, [25]) for Palaeogene deposits of the former USSR.

Palaeogene deposits of the same territories have been studied by Kozlova (1990, [13]; 1993, [14]); she established nine zonal subdivisions which correlated with radiolarian zones proposed by her for the Middle Volga, East Ural slope and West Siberia.

The existence of three zonal schemes for the same region reflects the difference in approach to the establishment of radiolarian biostratigraphical zonal subdivisions. First there is a problem because of the large number of hiatuses in the studied sections. Second there is a problem in deciding which species to use as a basis for a zonal scheme. This question was not clearly discussed by Nikitina & Zagorodnyuk (1981, [37]) or Zagorodnyuk (1981, [45]).

Lipman (1993, [25]) and Kozlova (1990, [13]; 1993, [14]) suggested that the number of events in the association of Radiolaria should be the main characteristic for the zonal boundary. However, Lipman tried to apply to the ga-Don Basin the scale she established for the western Siberia lowland and then tried to trace it to many regions of the country; whereas Kozlova attempted to apply (partially) the scale proposed by Foreman (1973) for the Gulf of Mexico. It is difficult to say now which attempt is the best and will be the most fruitful. In our opinion it is an important problem to be studied within the Peri-Tethys programme.

Middle Part of Volga River Flow (Middle Povolsh'e)

Radiolaria from this region have been studied by Lipman (1969, [19]) and Kozlova (1984a, b, [12]; 1990, [13]; 1993, [14]). For the Upper Palaeocene-Middle Eocene three versions of a zonal subdivision have been suggested. First, Kozlova (1984b, [12]) attempted to apply some biostratigraphical subdivisions suggested by Foreman (1973) for the Gulf of Mexico. Second, Kozlova (1990, [13]) proposed a zonal scheme based on morphotypic lineages of the genera *Axoprunum*, *Heliodiscus*, *Tripodiscinus*, *Clathrocyclas*, *Lychnocanium* and *Phormocyrtis*. This investigation showed the impossibility of using *Buryella clinata* and *Spongotrochus paciferus* as index-species for this region. Instead Kozlova suggested *Phormocyrtis striata* and *Heliodiscus lentis* zonal subdivisions for the Lower Eocene time interval. The first one (*P. striata*) of the index species is absent in a third version biostratigraphical scheme (Kozlova 1993, [14]). A new zone, *Heliodiscus hexasteriscus*, was suggested for the upper Lower Eocene and lower Middle Eocene deposits and the author puts a question mark for the Middle Eocene *L. separatum* Zone in the middle Volga area indicating that the establishment of this zonal subdivision is still under discussion.

Tourgaisk Trough and northern Pre-Aral

The Oligocene radiolarian association was discovered by Kestner (1973).

Investigations of Eocene Radiolaria in this area were carried out by Lipman (1965a, b, [17, 18]; 1969, [19]; 1972, [20]; 1975a, b, [21]) and Kozlova (1990, 1993). The most complete information about Palaeogene Radiolaria from the Tourgaisk Trough and northern Pre-Aral region is given in papers written by Lipman (1965, 1969, 1972, 1975a):

1. The distribution of ninety-eight radiolarian species in the Tourgaisk's Trough and northern Pre-Aral Eocene deposits is shown in the first paper (Lipman 1965a) of this series.

2. Two zonal subdivisions based on radiolarian data are established: *Spongurus biconstrictus* - Middle Eocene (lower part of Tasaransk series) and *Ellipsoxiphus chabakovi* - Upper Eocene

	FORAMINIFERAL ZONES OF THE SOUTHERN USSR (Krasheninnikov 1971; MSK USSR 1981, 1985)	RADIOLARIAN ZONES			
LATE EOCENE	*Globigeraspis tropicalis*	●	*Theocyrtis andriashevi*		
MIDDLE EOCENE	*Globigerina turcmenica*	●	*Ethmosphaera polysiphonia*		◆
		●	*Cyrtophormis (?) alta*		◆
	Hantkenina alabamensis	●	*Heliodiscus quadratus*		
	Acarinina rotundimarginata	●	*Lychnocanium separatum*		
	Acarinina bulbrooki	●	*Heliodiscus hexastericus*		
EARLY EOCENE	*Globorotalia aragonensis* s.l.	●	*Heliodiscus lentis*		◆
	Globorotalia subbotinae s.l.	●	*Petalospyris fiscella*		⬟
LATE PALEOCENE	*Acarina acarinata*		● *Phormocyrtis cubensis*	*P. foveolata*	
				T. sengilensis	
	Acarinina subspherica	●	*Buryella tetradica*		
	Globorotalia angulata s.l.	●	*Thecosphaera larnacium*		
EARLY PALEOCENE					
			Buryella (?) alifera	*Cromyocarpus (?) ovatus*	

● Planktonic foraminifers ◆ Nannoplankton ⬟ Dinoflagellates

FIG. 4. — Foraminiferal zones of South Eurasia compared to radiolarians zones (from Kozlova 1993).

(upper part of Tasaransk series).

3. *Spongurus biconstrictus* association of Radiolaria occurs together with foraminifers *Nummulites distans, N. murchissoni, Cibicides eocaenus, Bulimina mitgarsinae*. She believed these sediments to be analogous to the Alaisk stage of Central Asia, and to the Buchagsk series of the Russian platform.

4. *Ellipsoxiphus chabakovi* occurs together with the foraminifer *Spiroplectammina spectabilis*. The radiolarian association can be correlated with Upper Eocene deposits from the Turkestan Stage of Turkmenia, Kyzyl-Kum, and from the Ljulinvorsk Series of the western Siberian lowland.

5. In the deposits from the Saksaul Series one can see a third association of Upper Eocene (shallow water association) Radiolaria. The Upper Eocene age of the stratum is confirmed by molluscs (*Pectunculus aralensis*), and by foraminifers (*Bolivinopsis carinatiformis* etc).

6. The first assemblage of radiolarians was discovered in the deposits of the northern Aral Sea coast sections and on Cape Isendy-Aral in thin layered dark, greyish-grey clays, which were deposited above the nummulitic limestones, and also in marly clays and in the marls from wells of the Chagraisk plateau, in the Tumaly-Kolj village at Lake Tebez, in Chelkar, on Mount Tas-Aran,

AGE		FORMATION	Paleontological characteristics of zone	
			Foraminiferal zone	Radiolarian zone
PALEOGENE	UPPER EOCENE	Upper Coun	*Bolivina - Nonion curviseptum*	
			Globigerinoita index	*Cromyocarpius echinatus*
		Middle Coun	*Globigerina turcmenica*	*Sethopyramis victori* *Stylatractus pictus*
	MIDDLE EOCENE	Lower Coun	*Globigerinoides subconglobatus*	*Azerbaidjaniyus compositus : Stylotrochus schweeri*
			Globorotalia crassaformis	*Anthocyrtidium apsheronense Comutella fimbriata*
	LOWER EOCENE		*Globorotalia aragonensis - caucasica*	
			Globorotalia subbotinae	*Astrosestrum dialiensis* *Ellipsostylus ancorarius*
	UPPER PALEOCENE	*Sumgaitskaya*	*Globigerina velascoensis* and aglutinised foraminifera	

FIG. 5. — Scheme of Radiolaria and Foraminifera's zonal correlation in Shemakhino-Kobistanskaya and Apheronian peninsule areas of Azerbaidzan (Mamedov 1973b).

in the Turgay and in several wells along the River Ashchis and in the Irgis area. This complex is also traced in the Buchagsk Series in the southern part of the Russian Platform.

7. The second assemblage of radiolarians was encountered in sections of Mount Tas-Aran, on the northern coast of Tsche-Bas Bay, the Aral Sea and in several wells located on the Chagraisk Plateau in the Tumaly-Kolj village at Lake Tebez, in Chel-kar and in Turgay.

8. According to Lipman, the majority of radiolarian assemblages she investigated are characteristic of a shallow water basin. In addition to this general conclusion we should say, that in Middle Eocene radiolarian assemblages studied one can see many representatives of Nassellaria, which are not present in Late Eocene associations and this might indicate a difference in water depth.

The investigation carried out by Lipman on the Palaeogene biostratigraphy of this region was taken into account by Kozlova (1984, [12]). In her study of Palaeogene Radiolaria from the East Ural slope she incorporated in her new zonal scheme some zonal subdivisions proposed by Lipman. However, she referred her Upper Eocene *Heliodiscus lentis* Zone to the Lower Eocene and subdivided the *Ellipsoxiphus chabakovi* Zone into two new zones, the *Petalospyris fiscella* Zone and *Spongotrochus paciferus* Zone. She also introduced four new radiolarian species.

PRE-CASPIAN REGION

The Pre-Caspian territory is very large with its eastern part belonging to Turkestan, its western

part to Azerbaidzan, and the northern part to Russia. We start our description with the western part.

The western part of Pre-Caspian region (Azerbaidzan)

Shemakhino-Kobistanskaya and Apsheronian peninsula areas served as a basis for Mamedov's (1969a, b, c, [27-29]; 1970, [30]; 1973a, b, [31, 32]; 1975, [33]) investigations of Palaeocene-Eocene Radiolaria discovered in the Lower-Upper Coun Formation. Twenty-nine new taxa were described in his papers, and the first division of Eocene deposits according to radiolarians was established (Mamedov 1973a, [31]).

Species mentioned by Mamedov as characteristic of the western Pre-Caspian region are not found in the zonal scheme established by Lipman for the Apsheron Peninsula and Pre-Caucasus, despite the fact that both biostratigraphical subdivisions are based on radiolarian data and were correlated with the same foraminiferal zones. However, it is possible to carry an indirect, but not pure graphical, correlation between these two zonations for Lower-Upper Eocene deposits. Unfortunately, we can not say the same about the biostratigraphical scheme established for the northern Pre-Caspian region by Kozlova (1993, [14]).

In this case it is possible to use graphical correlation methods only since the author gave a comparison between her radiolarian biostratigraphical zonation with that based on foraminifers, which had been suggested by Krasheninnikov (1971) and approved by MSK USSR (1981, 1985) for the southern part of former USSR territory (this scheme is different to the one given in Mamedov's paper).

In a previous article Kozlova (1984a), using the same scale, correlated some, but not all, radiolarian zones with some diatom zones. Thus, *Buruella tetradica* zone (Foreman 1973) has been correlated with lower part of the *Trinacria ventriculosa* diatom zone (Gleser 1979), *Petalospyris fiscella* (Kozlova 1984a) with *Coscinodiscus payeri* (Gleser 1979), *Spongotrochus paciferus* (Kozlova 1984a) with the lower part of *Pyxilla gracilis* (?), and *Heliodiscus lentis* with the upper part of *Pyxilla gracilis* (?).

The eastern part of the Pre-Caspian region, Middle Asia

Radiolaria were found and studied in the Palaeogene deposits of Middle Asia (Lipman 1950, [16]; 1953; Chediya 1957, 1981; Moksyakova 1961, [35]; 1965, [36]; Kreidenkov & Chediya 1971; Kestner 1971, [10]) in exposures and wells of eastern Turkmenia, Bukharo-Khivinsk depression and south-western spurs of the Gissarsk mountain range, Tadzhiksk depression and Fergana. Eocene Radiolaria from the Turkestanian Stage have been studied by Lipman (1950, [16]). She described eighteen new species found in outcrops in Kyzyl-Kum, Tamdy, Shchulj trough, western slope of Tamdinsk stage, Ak-Oi, and in the wells near Dzhanhoi, Usun-Kuduk and Chetyr [16]. The next investigation of Upper Eocene radiolarians from Kumsky horizon of Western Turkmenia was carried out by Moksyakova (1961, [35]). The investigator described eighteen new taxa. Nevertheless the radiolarians association cannot be referred to a typical shallow water assemblage, because of the eight species of *Nassellaria* present. The next paper of Moksyakova (1965, [36]) was devoted to Upper Eocene Radiolaria from the Kuberlinsk and Kerestinsk horizons of south-eastern Turkmenia, Kyzyl-Kum and western Turkmenia (Ustyurt and Krasnovodsk plateau). The descriptions of ten new radiolarian taxa are given in this paper. The author presents a correlation (on the contrary to Chediya (1981) between the Bodraksky Stage of Crimea stratotype section and Kyberlinsky, Kerestinsky and Kymsky horizons of Turkmenia. She referred the Beloglinsky horizon of Turkmenia to Alminsky in Crimea. Kestner (1971, [10]) discovered twelve genera of *Nassellaria* (*Tripospyris, Lychnocanium, Sethopyramis, Sethocyrtis, Lophophaena, Podocyrtis, Theocorys, Theocyrtis, Tricolocampe, Theocampe, Lithostrobus, Eucyrtidium*) in Lower-Upper Eocene deposits of Beloglinsk, Kuberlinsk-Kerestinsk and Kumsk horizons. He referred Lower Eocene deposits to Bakhchisaraisky, Middle Eocene to Simferopolsky and Late Eocene to Bodraksky stages of the Black Sea stratotype section. The majority of these genera (eleven) were found in Upper Eocene deposits together with the following foraminifers:

Acarinina rotundimarginata, *Hantkenina alabamensis* and *Globigerinoides subconglobatus*. One genus was found in Early Eocene deposits together with *Globorotalia acqua* and *G. subbotinae*. The Middle Eocene radiolarian association occurs together with *Globorotalia aragonensis* and *Acarinina crassaformis*. In the paper written by Averburg & Kestner (1973) one can find the correlation made between radiolarian and foraminifer zones of this region.

Chediya (1973, [6]) investigated an Early Eocene association of Radiolaria in the Suzaksk area, a Middle Eocene association in the Alaisk area, and a Late Eocene association in deposits of the Bukharo-Khivinsk depression. Judging from lithologic composition of the rocks and fauna described in this publications, the sea in this area was during the Early Eocene a shallow water basin, which became deeper in the Middle Eocene and reached its maximum depth in the Late Eocene.

Unfortunately, information about Palaeocene radiolarian associations discovered in this area is incomplete. We found only one paper (Chediya *et al.* 1971, [5]) dealing with micro- and macrofaunal studies from the Bukharsk layers exposed in the mountain ranges of Peter-the-First, Khodzha-Kasian, Aryk-Tan, Istum-Tay and in the area Kichik-donguz elevation. Three new radiolarian taxa have been described in it. The association of Radiolaria occurs together with foraminifers. Underlying and overlapping layers contain coral, pelecypods, gastropods, brachiopods, ostracods, other macrofauna and small and large foraminifers.

CONCLUSION

As mentioned previously by Sanfilippo *et al.* (1985), in comparison with the amount of evidence available for calcareous microfossil groups, there are few localities for which the change from the Mesozoic to the Cenozoic radiolarian fauna can be traced. The available evidence indicates a profound decline in radiolarian diversity at the Cretaceous-Tertiary boundary. A high proportion of Mesozoic genera and families became extinct with only a few surviving into the Early Palaeocene. By early Eocene time, however, radiolarian genera and species had attained the diversity that they exhibited during the Cretaceous and throughout the later Cenozoic (Riedel & Sanfilippo 1981). Thus the radiolarians clearly fulfil one of the requirements for stratigraphic utility, namely taxonomic diversity - but what about their rate of evolutionary change ? Due to the great taxonomic diversity of the Cenozoic radiolarians, it is not wise to expect that all species will be comprehensively known in the near future. Therefore choices will have to be done on which ways the possible research will be conduct for radiolarian knowledge. Taxonomy must reflect phyletic relationships, not geometric ones as in the Haeckelian system. We are approaching this capability in some families but are far from it for most of the spumellarian families. To achieve such goals, it is necessary to record diversity and stratigraphical ranges from countries, which were somehow neglected until now, such as the Russian platform.

Studying the available literature in this field we have been faced with some problems. The majority of them deal with the establishment of a biostratigraphical scheme. Some of the problems have "objective" reasons:

1. The connection between some parts of Peri-Tethys was not constant during Palaeogene.

2. All processes of sedimentation were strongly influenced by transgressions and regressions within the basin; therefore there is very limited number of sections within the former Peri-Tethyan basin in which one does not find numerous hiatuses in radiolarian distribution.

3. Some parts of the Peri-Tethys at that time had long-lived basins with a well developed shallow water radiolarian fauna and this phenomena makes correlations between distant parts more difficult and indirect.

Besides these objective reasons there are some "subjective" reasons:

1. Scientists have been using different bases for the establishment of a biostratigraphic zonation.

2. The age determination of Palaeogene deposits in some regions (for example in Middle Asia) should be redone because the radiolarian assem-

blage was studied in thin sections only, or because the radiolarian association was described only at the generic level.
3. Long distance correlations requires that the taxonomy of many species be revised, as many identifications were based only on drawing.

Resolution of the difficulties mentioned above may help us to understand the reasons for the existence of two different zonal scales, one proposed by Lipman (1993) and the other by Kozlova (1993).
During the present review it became apparent that:
1. The presence of Oligocene-Lower Miocene radiolarian assemblages in the deposits exposed in Carpathian folded area had not been proven.
2. There was a contradiction between the palaeoenvironmental reconstructions of Lipman (1965) and of Kestner (1971), both of which were based on radiolarian associations from Eocene deposits of the Bukharo (Khivinsk depression and south) western spurs of the Gissarsk mountain range. According to Lipman's data the Upper Eocene radiolarians belong to a shallow water assemblage, but Kestner's data suggest that the Upper Eocene radiolarian association is characteristic of deep water conditions.

Finding the solutions to these two relevant problems would be appropriate and fruitful lines for future research within the Peri-Tethys project.

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TABLE 1. — Publications on Cenozoic radiolarians ordered by geographical regions (except publications dealing with the European part of the former Soviet Union [see Table 2]).

LOCATION	AGE	TOPIC	AUTHOR
	Quater.		Cachon J. *et al.* 1978
	Quater.	Evolut. Cytol. Ultrastruct.	Cachon J. & Cachon M. 1978a
	Quater.	Biol. Cytol. Ultrastruct.	Cachon J. & Cachon M. 1978b
	Quater.	Taxon. Evolut.	Cachon J. *et al.* 1977b
	Quater.	Biol. Cytol.	Cachon J. & Cachon M. 1977
	Quater.	Biol. Cytol.	Cachon J. & Cachon M. 1976a
	Czc	Taxon.	Goll R. M. 1972a
	Recent	Biol. Cytol. Physiol.	Cachon J. *et al.* 1977
	Quater.	Biol. Cytol.	Cachon J. & Cachon M. 1979
	Recent	Biol. Cytol. Physiol.	Cachon J. & Cachon M. 1980
	Czc	Evolut.	Kellogg D. E. 1983
	Czc	Evolut.	Kellogg D. E. 1980
	Quater.	Sedim. Climat. Season. product. Ecol.	Casey R. E. *et al.* 1971
	Czc	Evolut.	Kellogg D. E. & Hays J. D. 1975
	Czc	Taxon. Strat.	Campbell A. S. 1954
	Recent	Biol. Atlas General	Cachon J. & Cachon M. 1982a, b
	Recent	Ultrastruct. Reproduct. Biol. Cytol.	Cachon J. *et al.* 1985
	Czc	Taxon. N.Sp.	Campbell A. S. 1951
	Quater.	Biol. Cytol.	Cachon J. & Cachon M. 1975
	Quater.	Biol. Cytol.	Cachon J. & Cachon M. 1974
	Czc Mzc	Biostrat.	Boltovskoy D. 1988
	Recent	Preserv.	King K. 1977
		General Technics Preparation	Boltovskoy D. *et al.* 1983
	Quater.	Current Sedim.	Boltovskoy D. 1988
	Recent	Biol. Physiol. Reproduct.	Kling S. A. 1971a
	Mzc-Czc	General Strat. Evolut.	Kling S. A. 1978
		Preserv. Plankt.	Boltovskoy D. 1981
	Czc Mzc	DSDP6	Kling S. A. 1971b
	Recent	Physiol. Cytol.	King K. 1975
	Recent	Biol. Physiol. Cytol. Diagen.	King K. 1974
	Recent	Biol. Cytol. Skelet.	Cachon J. & Cachon M. 1972a, b, c
	Quater.	Biol. Skelet. Physiol.	Cachon J. & Cachon M. 1971b
	Quater.	Cytol. Biol.	Cachon J. & Cachon M. 1971a
	L.Eoc.	Taxon. N.Sp.	Brandt R. 1935
	Czc	Taxon Evolut.	Kellogg D. E. 1975
	Neogene	Strat. Environ.	Casey R. E. & Reynolds R. A. 1980
		Taxon. Biol. Strat. General	Goll R. M. & Merinteld E. G. 1979
	Czc	Taxon. N.Sp.	Haeckel E. 1881
	Czc	Taxon. Evolut. Skelet.	Dumitrica P. 1983
	Czc	Taxon. N.Sp.	Haecker V. 1908
	Czc	General Taxon.	Dumitrica P. 1979
	Czc Quater.	Taxon. N.Sp. Oc.	Haeckel E. 1887
	Czc	DSDP1	Ewing M. *et al.* 1969
		Taxon. Strat. General	Funnell B. M. & Riedel W. R. 1971
		Strat. Taxon. DSDP9	Goll R. M. 1972b
	Czc	Taxon. Evolut.	Goll R. M. 1976a
		DSDP38 Taxon.	Goll R. M. 1976b
	Recent Quater.	Plankt. Biot. Physiol.	Febvre J. 1982
	Neog.-Quater.	Evolut. Taxon.	Goll R. M. 1979
		Biol. Ecol.	Harbison G. R. *et al.* 1977

LOCATION	AGE	TOPIC	AUTHOR
	Czc-Ouater.	Taxon. N.Sp.	Dreyer F. 1889
	Paleog.	Biozon. Strat.	Cavelier C. & Pomerol C. 1977
	Czc-Ouater.	Biol. Evolut. Taxon. Cytol.	Hollande A. & Enjumet M. 1960
	Eoc.		Chediya D. M. 1973
	Czc-Ouater.	Biol. Cytol. Physio.	Hollande A. & Hollande E. 1976
	Mzc-czc	General review Sedim.	Hill W. 1912
	Ouater.	Biol. Physiol.	Herring P. J. 1979
	Czc	Evolut. Extinct. Ouater.	Hays J. D. & Shackleton N. J. 1976
	Mzc-Czc	DSDP16 Strat.	Dinkelman M. G. 1973
	Czc	Taxon.	Deflandre-Rigaud M. 1969
			Deflandre G. & Deflandre-Rigaud M. 1958
	Mzc-Czc	Distrib. Sedim. Paleog.	Hein J R. & Parrish J. T. 1987
	L.Pleist. Ouater.	Evolut.	Knoll A. H. & Johnson D. A. 1975
	Ouater.	Biol. Cytol.	Cachon J. & Cachon M. 1976b
		Climat. Ecol. Environ.	Kruglikova S. B. 1989
	Czc? Mzc?	Ecol. Oceanol. Biogeog.	Kruglikova S. B. 1984
	Mioc.-Ouater.	Strat. DSDP12	Benson R. N. 1972
	Ouater.	Biol. Physiol.	Anderson R. O. 1980
	Ouater.	Biol.	Anderson R. O. 1978b
		Biol.	Anderson R. O. 1978a
	Ouater.	Biol. Cytol.	Anderson R. O. 1976a
	Ouater.	Biol. Cytol.	Anderson R. O. 1976b
	Ouater.	Biol. Cytol.	Anderson R. O. 1977a
	Ouater.	Biol. Cytol.	Anderson R. O. 1977b
	Ouater. Recent	Ecol. Strat.	Kruglikova S. B. 1981
		Skelet. Physiol. Biol.	Anderson R. O. 1986a, b
		Biol. Skelet.	Anderson R. O. *et al.* 1989a, b
	Ouater.	Recent Biol.	Anderson R. O. & Rottger R. 1986
	Ouater.	Biol. Skelet.	Anderson R. O. *et al.* 1986b
		Biol. Cytol. Physiol.	Anderson R. O. 1983
	Neog.-Ouater.	Evolut. Taxon. Skelet. Strat. Oceano.	Lazarus D. B. *et al.* 1985
		Biol. Cytol.	Anderson R. O. 1984
		Evolut.	Lazarus D. B. *et al.* 1982
	Czc Ouater.	Biol. Physiol. Cytol.	Anderson R. O. 1985b
		Evolut. Taxon. Biol. Biogeog.	Baker C. W. & Johnson D. A. 1982
		Biol. Evolut.	Anderson R. O. 1985a
	Ouater.	Biol. Skelet.	Anderson R. O. 1981
	Czc-Ouater.	Biol. Physiol.	Lecher F. 1978
		Biol. Cytol.	Anderson R. O. 1976a
	Ouater.	Ecol. Biol.	Anderson R. O. *et al.* 1985
	Recent Ouater.	Biol. Skelet. Cytol.	Anderson R. O. & Botfield M. 1983
		Skelet. Biol.	Anderson R. O. & Swanberg N. R. 1981
	Ouater.	Biol. Cytol.	Anderson R. O. *et al.* 1983
	Ouater.	Biol. Skelet.	Anderson R. O. & Bennett P. 1985
	Ouater.	Biol.	Anderson R. O. *et al.* 1984
	Ouater.	Skelet. Evolut.	Bjorklund K. R. & Goll R. M. 1979b
	Ouater.	Biol.	Anderson R. O. *et al.* 1986a
	Ouater.	Sedim.	Anderson R. O. 1986b
		Biol. Ecol. Physiol.	Anderson R. O. *et al.* 1989b
	Czc	DSDP31	Ling H. Y. 1975
	Czc	DSDP40	Pisias N. G. & Moore T.C. Jr 1978
	Ouater.	Biol. Taxon. Skelet.	Petrushevskaya M. G. *et al.* 1976

LOCATION	AGE	TOPIC	AUTHOR
		Taxon. DSDP14	Petrushevskaya M. G. & Kozlova G. E. 1972
		Taxon. Strat.	Riedel W. R. & Sanfilippo A. 1977
	Czc	Taxon. Strat. Evolut.	Riedel W. R. & Sanfilippo A. 1978a
	Eoc.-Qligoc.	Geochron.	Riedel W. R. & Sanfilippo A. 1986
	Recent	Phaeodar. Preserv.	Runeva I. P. & Reshetnyak V. V. 1979a, b
		Taxon. Strat. Evolut.	Riedel W. R. & Sanfilippo A. 1982
		Taxon. Strat. Evolut. Skelet.	Riedel W. R. & Sanfilippo A. 1981
	Recent	Plankt. Sedim. Environ.	Riedel W. R. & Saito T. 1979
	Czc	Skelet. Taxon. Onlog. Phylo.	Petrushevskaya M. G. 1987
	Pzc Mzc Czc	Taxon. Skelet.	Petrushevskaya M. G. 1986
	Czc	Strat. DSDP	Olson R. K. & Goll R. M. 1970
	Czc Quater.	Skelet.	Nishimura A. 1982
	Mioc.-Ouater.	Bibliog.	Nigrini C. A. & Moore T. C. 1979
	Mioc.	Taxon.	Nakaseko K. *et al.* 1983
		Biol. Taxon. Plankt.	Page F. 1984
		Taxon. Skelet.	Petrushevskaya M. G. 1975b
	Pzc Mzc Czc	Taxon. Evolut. Skelet.	Petrushevskaya M. G. 1981a
		Taxon. Skelet.	Petrushevskaya M. G. 1975a
	Ouater.	Taxon. Paleogeog. Plankt.	Petrushevskaya M. G. 1972b
	Ouater.	Taxon. Plankt.	Petrushevskaya M. G. 1972a
	Recent	Sedim.	Takahashi K. & Ling H. Y. 1984
	Recent	Sedim. Preserv.	Takahashi K. 1984
	Recent	Preserv. Sedim.	Takahashi K. 1983
		Paleog. Geogr.	Worsley T. R. & Jorgens M. L. 1974
	Mzc Czc	Techn.	Yogo S. 1982
	Recent	Biol.	Swanberg N. R. *et al.* 1986a, b, c
	Recent	Biol. Sketet. Taxon. N.Sp.	Swanberg N. R. *et al.* 1985
	Neog.	Taxon. Strat. Zones	Sanfilippo A. *et al.* 1985b
		Taxon. Skelet.	Schaaf A. 1981
	Neog.	Taxon.	Sanfilippo A. & Riedel W. R. 1980
	Neog.	Taxon. Strat.	Sanfilippo A. Riedel W. R. 1970
	Neog.	Taxon. Strat.	Sanfilippo A. 1980
		General	Shrock R. R. & Twenhofel W. H. 1979
	Recent	Biol.	Swanberg N. R. & Anderson R. O. 1985
	Czc Recent	Biol.	Swanberg N. R. 1984
	Czc	Biol. Environ.	Swanberg N. R. 1983
	Mzc Czc	Environ. Ecol. Geogr. Current	Spaw J. M. *et al.* 1979
	Czc	DSDP27	Renz G. W. 1974
	Oligoc.-Mioc.	Evolut.	Moore T. C. 1972
	Czc	Strat. Taxon. DSDP8	Moore T. C. 1971
	Czc Mzc PZ	General	Lipman R. Kh. *et al.* 1979
	Paleogene Mzc	Strat.	Lipman R. Kh. 1979b
	Czc Mzc	Evolut. Taxon.	Lipman R. Kh. 1975c
	Czc Mzc PZ	General Taxon. Evolut.	Lipman R. Kh. 1979a
	Czc-Quater.	Biogeog. Ecol. Climat.	Morley J. J. 1980
	Czc Quater.	Biogeog. Plankt.	Mast H. 1910
	Czc Quater.	Plankt. Evolut. Taxon.	Merinfeld E. G. 1978
	Eoc.	Taxon. Strat.	Mato C. Y. & Theyer F. 1980
	Cret.-Czc	Taxon. Strat. DSDP10	Foreman H. P. 1973
	Cret.-Czc	Taxon. Evolut.	Dumitrica P. 1985
	Czc	General Taxon.	Foreman H. P. & Riedel W. R. 1972
	Czc Mzc?		Levykina I. E. 1984

LOCATION	AGE	TOPIC	AUTHOR
	Czc? Mzc?	Plankt.	Meyen F. J. F. 1961
	Paleog.-Quater.	Taxon. Strat.	Sanfilippo A. & Riedel W. R. 1982
	Pzc Mzc Czc	Taxon.	Riedel W. R. 1967a
	Pzc Mzc Czc	Taxon.	Riedel W. R. 1967b
	Quater.	Skelet. Preserv. Struct	Bjerklund K. R & Goll R. M. 1985a, b
		Strat. Taxon. DSDP17	Moore T. C 1973a
Atlant.		Taxon. Strat. DSDP1	Riedel W. R. & Sanfilippo A. 1970
Amer.C. Atlant.W. Carib.		Taxon. Strat. DSDP15	Riedel W. R. & Sanfilippo A. 1973
Amer.C. Barbados Les Antilles	Paleoc.-Mid.Miocene		Biju-Duval B. *et al.* 1985
Amer.C. Carib.	Czc	Taxon.	Riedel W. R. & Hays J. D. 1969
Amer.C. Carib.	Eoc. Oligoc.	Strat. Tektite Extinc.	Maurrasse F. & Glass B. P. 1976
Amer.C. Carib.	Czc	Paleog. Ecol. Climat. Sedim.	Maurrasse F. 1976
Amer.C. Carib. Medit. Pacif.	Paleoc.-Neog.	Taxon. Strat. DSDP10	Sanfilippo A. & Riedel W. R. 1973
Amer.C. Carib. Cuba	Czc		Albin E.-F. 1986
Amer.C. Carib. Cuba La Habana	Paleoc.-Eoc.		Albin E.-F. Fernandez G. 1985
Amer.C. Costa Rica	L.Miocene	DSDP 69	Hein J. R. *et al.* 1983b
Amer.C. W.Costa Rica.	Cret.-Paleog.	Sedim.	Hein J. R.*et al.* 1983a
Amer.C. Barbados	L.Eoc.-E.Olig.	Evolut. DSDP 77B 289	Sanfilippo A. 1988
Amer.C. Barbados Atlant.W. Carib.	Eoc.	Evolut.	Sanfilippo A. *et al.* 1985a
Amer.N.	Eoc.-Oligoc.	Extinct. Evolut. Biozon.	Glass B. P. *et al.* 1978
Amer.N.	Eoc.-Oligoc.	Tektite Evolut. Extinct.	Glass B. P. & Crosbie J. R. 1982
Amer.N. Alabama Mississippi	Eoc.	Taxon. Strat.	Cunningham K. M. 1895
Amer.N. Asia Australia Africa	Eoc.	Extinct. Evolut. Tektite	Glass B. P. *et al.* 1979
Amer.N. C.Calif.	Eoc.	Taxon. Strat. Environ.	Blueford J. R. 1988
Amer.N. Calif.	L.Eoc.	Taxon. N.Sp.	Clark B. L. & Campbell A. S. 1942
Amer.N. Calif.	Eoc.	Taxon. N.Sp.	Clark B. L. & Campbell A. S. 1945
Amer.N. Calif.	Czc	Sedim.	Conrad C. & Ehlig P. L. 1983
Amer.N. Calif.	Czc Mzc?	Sedim.	Hinde G. J. 1894
Amer.N. Calif.	Mioc.	Taxon. N.Sp.	Campbell A. S. & Clark B. L. 1944
Amer.N. Calif.	Recent	Current Climat. Biogeog. Environ.	Bolovskoy D. & Riedel W. R. 1985
Amer.N. Calif.		Biogeog. Ecol.	Kling S. A. 1977
Amer.N. Calif.	Recent	Current Climat. Environ.	Bolovskoy D. & Riedel W. R. 1987
Amer.N. Calif.	Czc Mioc.	Strat.	Poore R. Z. *et al.* 1981
Amer.N. Calif.	M.Mioc.	Strat.	Price A. B. 1975
Amer.N. Calif. Antar.C.	Neogene	Strat. Climat. Environ. Ecol.	Casey R. E. 1972
Amer.N. Calif. Barbados	Paleog.		Saunders J. B. *et al.* 1984
Amer.N. Calif. Francisc.	Czc	Taxon.	Riedel W. R. & Schlocker J. 1956
Amer.N. Calif. Pacif.	Quater.	Strat. Taxon.	Benson R. N. 1966
Amer.N. Calif. Monterey	Mioc.	Strat.	Price A. B. 1975
Amer.N. Calif. Monterey Baja	Mioc.-Plioc.	Strat. Environ.	Weaver F. M. *et al.* 1981
Amer.N. Carib. Atlant. Mexico		Extinct Tektite Evolut.	Glass B. P. & Zwart M. J. 1979
Amer.N.	Eoc.-Oligoc.	Evolut. Extinct.	Glass B. P. & Zwart M. J. 1977
Amer.N. Maryl.	Mioc.	Taxon.	Martin G. C. 1904
Amer.N. N.Calif.	Eoc.	Strat.	Blueford J. R. & Brunner Ch. 1984
Amer.N. S.Calif. Pacif.	Neog.	Ecol. Environ.	Casey R. E. *et al.* 1972
Amer.N. SE.Missouri	Paleoc.-Eoc.	Taxon.	Frizzell D. L. & Middour E. S. 1951
Amer.N. USA	Neog.		Palmer A. 1984
Amer.N. W.C.Calif.	Eoc.	Environ. Oceano.	Blueford J. R. & White L. D. 1984
Amer.S. Chile Tripoli		Taxon. N.Sp. Strat.	Frenguelli J. 1941
Amer.S. S.Brasil	Quater.		Kolzian S. C. B. 1984
Amer.S. Peru Pisco-F°	Mioc.	Sedim.	Mertz D. 1966
Antar.	Czc-Quater.	Climat. Environ. N.Sp.	Hays J. D. 1965

LOCATION	AGE	TOPIC	AUTHOR
Antar.	Quater.	Sedim.	Hays J. D. 1967
Antar.	Plioc-Quater.	Climat.	Keany J. & Kennett J. P. 1972
Antar.	Cenozoic	Strat. Biogeog.	Kennelt J. P. 1976
Antar.	Quater.	Environ.	Kennett J. P. 1979
Antar.	Plioc.	Taxon. Strat.	Keany J. 1979
Antar.	Neog.	Taxon.	Coco B. C. 1982
Antar.	Mioc.-Quater.	Strat.	Nakaseko K. 1959a
Antar.	Mioc.-Quater.	Strat.	Nakaseko K. & Nishimura A. 1982
Antar.	Czc Quater.	Plankt.	Schroder O. 1906
Antar.	Czc	Taxon. Phaeodar.	Popofsky A. 1908
Antar.	Quater.	Taxon. Climat.	Riedel W. R. 1958
Antar.	Czc-Recent		Popofsky A. 1917
Antar.	Czc-Recent	Ecol.	Popofsky A. 1913
Antar.	Czc-Quater.	Taxon. Plankt.	Petrushevskaya M. G. 1967
Antar.	Czc	Taxon.	Popofsky A. 1912
Antar. Arct. Polar.	Czc-Recent	Climat. Ecol.	Popofsky A. 1920
Antar. Atlantic	Plio-Pleist. Neog. Quater.	Strat. Antar.	Abelmann A. & Gersonde R. 1988
Antar. Pacif.S.	Quater.	Taxon. Plankt.	Petrushevskaya M. G. 1979b
Antar. SE.Indian Oc.	Quater.(L.Pleist.)	Environ. Biogeog.	Dow R. L. 1978
Antar.Indian Oc.	Quater.	Taxon. Skelet.	Petrushevskaya M. G. 1975c
Antar.S.	Quater.	Taxon	Bolfovskoy D. & Vrba A. 1988
Antarct.	Quater.	Taxon. Plankt.	Petrushevskaya M. G. 1974
Antarctic	Quater.	Earth Rotation Cyclicity	Hays J.D. *et al.* 1976
Antarctic	Quater.	Climat. Extinct.	Hays J. D. & Donahue J. G. 1972
Antarctic		Biostrat DSDP	Chen P. H. 1975
Antarctic	Oligoc.-Neog.	Taxon. Strat. DSDP	Chen P. H. 1974
Antarctic	Quater.	Climat. Biozon.	Hays J. D. & Opdyke N. D. 1967
Arctic	Quater.	Taxon. N.Sp.	Hulsemann K. 1963
Arctic Pacif.? Boreal	Paleog.-Recent		Kozlova G. E. 1984a
Asia Australia	Czc? Mzc?	Sedim.	Kobayashi T. 1944
Asia Centr.Japan	Miocene	Taxon.	Tanaka H. *et al.* 1983
Asia China		Taxon. N.Sp.	Xinghui S. 1982
Asia China	Czc	Biol.	Xinghui S. & Zhiyuan T. 1985
Asia China	Mzc Czc	Taxon. Skelet. Evolut.	Tan Z.-Y. Su S.-H. 1981
Asia China Gyangze Xizang		Plankt.	Wang Yujing & Sheng Jinzhang 1982
Asia China Himalaya Tibet Xizang	Czc		Wu Hao-rue 1980
Asia China Sea E.	Czc Quater.	Environ. Taxon.	Chen-Wenbin-Wang Baoyong 1982
Asia China Xisha Islands	Czc	Taxon. Skelet.	Zhiyuan T. & Xinghui S. 1981
Asia E.China Sea	Czc		Tan Zh. Su X. 1982
Asia E.China Sea		Strat. Geogr.	Zhiyuan T. *et al.* 1978
Asia E.China Sea	Czc	Strat.	Zhiyuan T. & Tsorun T. 1976
Asia Europe ex-Ussr pre-Causasus	Paleoc.-Eoc.		Lipman R. Kh. 1984b
Asia ex-Ussr N.Sakhalin	Neog.		Runeva N. P. 1984
Asia Himalaya Tibet Ladakh	Eoc.	Strat.	Colchen M. *et al.* 1987
Asia Indones. S.China Sea	Czc Quater.		Ling H. Y. 1972
Asia Japan	Czc	Biozon. Strat.	Kitazato H. 1975
Asia Japan	Czc Mzc Pzc	General	Kimura T. 1944
Asia Japan	Czc Mzc		Kobayashi T. & Kimura T. 1944
Asia Japan	Czc Mzc	Strat.	Ichikawa K. 1946
Asia Japan	Czc Mzc		Ichikawa K. 1953
Asia Japan	Neogene		Sugano K. & Nakaseko K. 1971

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Asia Japan	Neogene		Sugano K. & Nakaseko K. 1970
Asia Japan	Mioc.-Quater.	Strat.	Nakaseko K. 1956
Asia Japan	Neogene		Sugano K. & Nakaseko K. 1973
Asia Japan	Neogene		Sugano K. & Nakaseko K. 1972
Asia Japan	Mzc? Czc?	Sedim.	Sugano K. 1986
Asia Japan	Mioc.	Strat.	Nakaseko K. 1954
Asia Japan	Mzc Czc	Review	Sugano K. 1975
Asia Japan	Czc		Ling H. Y. & Kurihara K. 1972
Asia Japan	Mioc.	Strat.	Nakaseko K. 1955
Asia Japan	Neog.		Sugano K. & Nakaseko K. 1968
Asia Japan	Mioc.-Quater.	Strat.	Nakaseko K. 1958
Asia Japan	Mioc.	Strat.	Nakaseko K. & Nishimura A. 1974
Asia Japan	Neogene	Strat.	Nakaseko K. & Sugano K. 1973
Asia Japan	Neogene	Strat.	Nakaseko K. *et al.* 1972 a, b
Asia Japan		Geol. Strat.	Nakaseko K. *et al.* 1979a
Asia Japan	Czc	Strat.	Nakaseko K. *et al.* 1979b
Asia Japan	Czc		Takayanagi Y. *et al.* 1978
Asia Japan	Mioc.	Taxon. Strat.	Nakaseko K. *et al.* 1982
Asia Japan	Mioc.-Quater.	Strat.	Nakaseko K. & Sugano K. 1972
Asia Japan	Czc	Strat.	Nakaseko K. 1979
Asia Japan	Neogene		Sugano K. & Nakaseko K. 1975
Asia Japan	Mioc.-Quater.	Strat.	Nakaseko K. & Chiji M. 1964
Asia Japan	Cret.-Czc	Strat.	Nakaseko K. *et al.* 1965
Asia Japan	Neogene	Taxon.	Nakaseko K. & Nishimura A. 1971
Asia Japan		Strat.	Nakaseko K. & Sugano K. 1970
Asia Japan	Plioc.-Quater.	Strat.	Nakaseko K. 1964
Asia Japan	Mioc.-Quater.	Strat.	Nakaseko K. 1971 a, b
Asia Japan	Plioc.-Quater.		Nishimura A. & Yamauchi M. 1984
Asia Japan	Mioc.-Quater.	Strat.	Nakaseko K. 1959b
Asia Japan			Okada H. *et al.* 1982
Asia Japan	Czc		Sugano K. *et al.* 1980
Asia Japan	Mioc.-Quater.	Strat.	Nakaseko K. 1969
Asia Japan	Neog. Quater.		Sugano K. & Nagata K. 1978
Asia Japan	Mioc.-Quater.	Strat.	Nakaseko K. 1963
Asia Japan	Mioc.-Quater.	Strat.	Nakaseko K. 1960
Asia Japan	Mioc.	Strat.	Takayenagi Y. *et al.* 1976
Asia Japan C.Pacif. Amer.N. Calif.	Mioc.-Plioc.	Strat.	Nagata K. 1982b
Asia Japan	Czc	Skelet.	Nishimura H. 1986
Asia Japan E.Hokkaido		Biostrat. Preserv. Diagen.	Nagata K. 1986
Asia Japan Equat.Pacif.		Strat. Plankt.	Takayanagi Y. *et al.* 1979 a, b
Asia Japan Hokkaido	Mioc.	Strat.	Nagata K. & Ichinoseki T. 1982
Asia Japan Hokkaido	Mioc.-Quater.	Strat.	Nagata K. 1979
Asia Japan Honshu	Mioc.	Biozon.	Oda M. *et al.* 1983
Asia Japan Honshu	Czc	Strat.	Iijima A. *et al.* 1981
Asia Japan NE.Honshu		Strat.	Amano K. 1980
Asia Japan Pacif.		DSDP56 Strat.	Barron J. A. *et al.* 1980
Asia Japan Sendai	Czc?		Oda M. & Sakai T. 1977
Asia Japan Shimanto	Czc	Taxon.	Ishikawa T. 1982
Asia Japan W.Hokkaido		Strat.	Nagata K. 1982a
Asia Japan	Oligoc.-Neog.		Ling H. Y. 1987
Asia Japan.C.	Neog.		Sugano K. 1982a
Asia Japan.C.		History Review	Sugano K. 1982b

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Asia Japan.C.	Mioc.		Sugano K. 1976
Asia Japan.SW.	Czc Mzc		Ishida S. 1979
Asia Japan.SW. Shikoku			Yamasaki T. 1987
Asia Japan.SW. Maizuru Gr.		Biostrat.	Nishimura K. & Ishiga H. 1987
Asia Pacif.			Sakai T. *et al.* 1981
Asia Pacif. Celebes Indones.			Hinde G. J. 1917
Asia SE.Middle Tadzhikistan	Paleog. Eoc.		Chediya D. M. *et al.* 1971
Atlant. Norway	Quater.	Skelet. Taxon.	Bjørklund K. R. 1974a
Atlant.	Mzc?	Taxon.	Ehrenberg C. G. 1854
Atlant.	Quater.	Sedim.	Caulet J. P. & Clocciatti M. 1975
Atlant.	Quater.	Environ. Biogeog.	Bjørklund K. R. & Swanberg N. R. 1987
Atlant.	Quater.		Kozlova G. E. 1980
Atlant.	Recent	Biot.	Kleijne A. 1987
Atlant.	Cret.-Quater.	Strat. DSDP2	Cita M.B. *et al.* 1970
Atlant.	Czc	Biogeog.	Casey R. E. & McMillen K. J. 1977
Atlant.	Quater.	Strat. Climat.	Morley J. J. & Shackleton N. J. 1978
Atlant. Açores	Czc-Recent	Plankt.	Muzavor S. N. X. 1981
Atlant. Amer.C. Carib.	Quater.	Environ. Biogeog.	Casey R. E. 1971a
Atlant. Amer.C. Carib.	Recent	Biol.	Swanberg N. R. *et al.* 1986 a, b, c
Atlant. Amer.C. Carib. Gulf Mexico	Quater.	Ecol. Biogeog.	Casey R. E. *et al.* 1979a
Atlant. Amer.C. Carib. Gulf-Coast	Quater.	Environ. Ecol. Current Plankt.	Casey R. E. *et al.* 1981
Atlant. Amer.C. Carib. S.Texas	Quater.	Ecol. Environ. Current	Leavesley A. *et al.* 1978
Atlant. Boreal Norway	Quater.	Current Biogeog. Sedim.	Jansen E. & Bjørklund K. R. 1985
Atlant. Boreal Norway		Strat. DSDP38	Dzinoridze R. N. et al. 1976
Atlant. Boreal Norway Greenland	Neog.-Quater.	Evolut. Strat.	Goll R. M. & Bjorklund K. R. 1980
Atlant. Boreal Norway Greenland		Taxon. N.Sp.	Goll R. M. & Bjørklund K. R. 1985
Atlant. Carib.	Quater.	Environ. Ecol.	Casey R. E. 1971b
Atlant. Carib. Barbados			Ehrenberg C. G. 1846
Atlant. Carib. Blake Bahama	Czc	DSDP44	Weaver F. M. & Dinkelman M. G. 1978
Atlant. Europe	Czc Mzc		Swain F. M. 1977
Atlant. Rochall Plateau	Mioc.	DSDP81 Strat.	Westberg-Smith M. J. & Riedel W. R. 1984
Atlant. S.Brasil	Czc		Kotzian S. B. & Eilert V. P. 1985
Atlant. W.Norway	Czc Quater.	Sedim.	Bjørklund K. R. 1973
Atlant. Antar.	Neog.	Biostrat.	Abelmann A. 1988
Atlant.E. Angola	Quater.	Biogeog. Environ.	Bjorklund K. R. & Jansen J. H. F. 1984
Atlant.E. Morocco	Mioc.	DSDP50 Strat.	Westberg M. J. *et al.* 1980
Atlant.E. NW.Africa	Quater.	Biogeog. Ecol.	Labracherie M. 1980a
Atlant.E. NW.Africa	Quater.	Current	Labracherie M. 1980b
Atlant.E.Tropic.		DSDP41 Strat. Taxon.	Johnson D. A. 1978
Atlant.N. Boreal Norway	Quater.	Biol. Skelet. Plankt.	Swanberg N. R. & Bjorklund K. R. 1987b
Atlant.N. Boreal Norway	Recent	Plankt. Ecol. Environ.	Swanberg N. R. & Bjorklund K. R. 1986
Atlant.N. Boreal Norway	Quater.	Biol. Plankt. Ecol.	Swanberg N. R. & Bjørklund K. R. 1987a
Atlant.N.	Quater. Recent	Biogeog.	Kleijne A. 1984
Atlant.N.	Quater.	N.Sp. Biogeog. Skelet.	Bjorklund K. R. 1976a
Atlant.N.	Quater.	Biogeog. Sedim.	Goll R. M. & Bjørklund K. R. 1971
Atlant.N.		Strat. Taxon.	Riedel W. R. 1957a
Atlant.N.	Czc	DSDP94	Westberg-Smith M. J. *et al.* 1986
Atlant.N.	Czc-Quater.	Taxon. Plankt. Skelet.	Petrushevskaya M. G. 1969
Atlant.N. Antar. Pacif.N.	Neog.		Lombari G. & Lazarus D. B. 1988
Atlant.N. Boreal Norvegian Sea		Strat.	Bjorklund K. R. 1976b
Atlant.N. Boreal Norway	Quater.		Jörgensen E. 1900
Atlant.N. Boreal Norway		DSDP Taxon.	Petrushevskaya M. G. & Kozlova G. E. 1979

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Atlant.N. Boreal Norweg.-Greenland	Quater.	Taxon.	Petrushevskaya M. G. & Bjørklund K. R. 1974
Atlant.N. Boreal Norwegian Sea	Quater.	Climat. Environ.	Bjørklund K.R. *et al.* 1979
Atlant.N. Boreal Norwegian Sea		DSDP38	Jouse A. P. *et al.* 1979
Atlant.N. Boreal Norwegian Sea	Eoc.	Taxon. N.Sp.	Bjørklund K. R. & Kellogg D. E. 1972
Atlant.N. Boreal Norweg.-Greenl. Sea	Quater.	Climat. Environ.	Bjørklund K. R. & Goll R. M. 1979a
Atlant.N. N.Sea	Recent	Strat.	Bjorklund K. R. 1985
Atlant.N. N.Sea (Skagerrak)	Quater.	Environ. Sedim.	Bjørklund K. R. *et al.* 1985
Atlant.N. N.Sea (Skagerrak)	Quater.	Strat.	Bjorklund K. R. 1985
Atlant.N. N.Sea	Quater.	Strat. Biogeog	Bjørklund K. R. 1983
Atlant.N. Norwegian-Greenland	Quater	Evolut.	Kozlova G. E. & Petrushevskaya M. G. 1979
Atlant.N. Reykjanes Ridge	Czc	Strat. Taxon. DSDP49	Ling H. Y. 1979
Atlant.N. W.Norway Biogeog.	Recent	Season. product. Climat.	Bjørklund K. R. 1974b
Atlant.NE.	Quater.	Current	Labracherie M. & Moyes J. 1978
Atlant.NE.	Neog.	Taxon. Strat. DSDP48	Santilippo A. & Riedel W. R. 1979
Atlant.NE. Mediter.	Cret.-Quater.	DSDP13 Taxon. Strat.	Dumitrica P. 1973a.
Atlant.NE. S.Norwegian Sea	Quater.	Biogeog. Ecol.	Labracherie M. 1978
Atlant.NW.	Czc	DSDP 93	Nishimura A. 1987
Atlant.S.		Environ. Ecol.	Boltovskoy D. 1980
Atlant.S.	Quater.	Sedim. Biogeog.	Goll R. M. & Bjørklund K. R. 1974
Atlant.S.	Czc-Quater.	Biogeog. Ecol. Climat.	Morley J. J. 1979
Atlant.S. Antar. S.W.Indian. Oc.		Biogeog. Current Sedim. Environ.	Lozano J. A. & Hays J. D. 1976
Atlant.SW.		Biogeog.	Boltovskoy D. 1981a, b
Atlant.SW.	Quater.	Recent Biogeog.	Boltovskoy D. 1978a, b
Atlant.SW.	Quater.		Boltovskoy D. & Riedel W. R. 1980
Atlant.SW.	Recent	Plankt. Biogeog.	Boltovskoy D. 1982
Atlant.SW.	Recent	Biogeog. Current Environ.	Boltovskoy D. 1986
Atlant.SW. Antar.	Quater.		Eilert V. P. 1985
Atlant.SW.	Recent	Plankt. Biogeog.	Boltovskoy D. 1979
Atlant.W Carib. Amer.C.Barbados	Eoc.	Evolut.	Santilippo A. *et al.* 1985a, b
Atlant.W. Amer.C. Carib. Mexic.	Quater.	Ecol. Biogeog. Sedim. Plankt.	McMillen K. J. & Casey R. E. 1978
Atlant.W. Amer.C. Carib. Mexico	Quater.	Ecol. Biogeog. Preserv.	McMillen K. J. 1977a
Atlant.W. Amer.C. Carib. Mexico	Quater.	Ecol. Biogeog. Preserv. DSDP66	McMillen K. J. 1982
Atlant.W. Amer.C. Carib. Mexico	Czc Quater.	Ecol. Biogeog. Preserv.	McMillen K. J. 1977b
Atlant.W. Barbados Antilles	Czc	DSDP	Renz G. W. 1984
Atlant.W. Carib.	Neog.	Taxon. Strat.	Santilippo A. & Riedel W. R. 1976
Atlant.W. Carib. Gulf Mexico	Plio-Quater.	Plankt. Taxon. Environ.	Casey R. E. *et al.* 1979c
Atlant.W. Gulf Mexico	Quater.	Ecol. Sedim.	Casey R. E. *et al.* 1979b
Atlant.W. Gulf Mexico Carib. Calif.	Czc Quater.	Strat. Environ. Plankt. Ecol.	Wigley C. R. 1982
Atlant.W. Gulf Stream	Recent	Biol.	Swanberg N. R. & Anderson R. O. 1981
Atlant.W.Tropic.	Quater.	Flux Sedim. Current Preserv. Skelet.	Takahashi K. & Honjo S. 1983
Atlant.W.Tropic.	Quater.	Flux Sedim. Current Preserv.	Takahashi K. & Honjo S. 1981 a, b
Atlantic	Recent	Ecol. Biol.	Swanberg N. R. & Harbison G. R. 1980
Atlantic	Czc-Quater.	Strat.	Morley J. J. & Shackleton N. J. 1978
Atlantic	Czc	Taxon. DSDP	Riedel W. R. 1971a
Atlantic Antar.	Plio-Pleist. Neog.	Strat. Antar.	Abelmann A. & Gersonde R. 1988
Atlantic.S.	Quater.	Biogeog. Ecol. Climat.	Morley J. J. & Hays J. D. 1979a
Banda		Taxon. N.Sp. Sedim.	Harting P. 1863
Calif. El Nino	Quater.	Climat. Current Environ. Ecol.	Casey R. E. *et al.* 1987
Eurasia ex-Ussr	Paleog.	Boreal Strat.	Lipman R. Kh. 1985
Europe Austria	Mioc.	Taxon.	Bachmann A. *et al.* 1963
Europe Belgium Ieper	Eoc.		Willems W. 1981
Europe Carpathian Poland	Mioc.		Barwicz-Piskorz W. 1978

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Europe France (Paris Bas.) Belgium	Czc	Sedim. Petro.	Cayeux L. 1897
Europe Italy Calabria	Plio-Quater.	Tripoli Strat. Sedim.	Guerrera F. 1881
Europe Italy Calabria	Plioc.		Sanfilippo A. 1988
Europe Italy Sicily Tripoli	Mioc.		Stohr E. 1880
Europe Italy Sicily Zancle	Plioc.	Taxon. Strat.	Riedel W. R. *et al.* 1974
Europe Medit.	Quater.	Preserv. Sedim. Taxon.	Caulet J. P. 1972
Europe Medit.	Recent	Plankt. Climat. Season Ecol.	Massera Bottazzi E. & Andreoli M. G. 1977 a, b
Europe Medit.	Czc Recent	Biogeog. Current Environ.	Massera Bottazzi E. *et al.* 1986
Europe Medit.	Czc Recent	Plankt. Environ. Ecol.	Massera Bottazzi E. *et al.* 1984
Europe Medit. Tirreno	Quater.	Taxon.	Poluzzi A. 1982
Europe N.France	Eoc.	Sedim.	Cayeux L. 1891
Europe.E. Brno-Kralovo	Mioc.	Taxon	Slama P. 1982
ex-Ussr	Czc		Goltman E. V. 1970
ex-Ussr	Eoc.	Taxon. N.Sp.	Lipman R. Kh. 1969
ex-Ussr	Paleogene Czc Eoc.		Lipman R. Kh. 1972
ex-Ussr	Eoc.	Biozon.	Zagorodnyuk V. I. 1981
ex-Ussr	Paleogene	Strat.	Lipman R. Kh. 1975b
ex-Ussr Crimea Minor Asia	Ecol.		Tchedya D. M. 1981
ex-Ussr Don River N.Emba	L.Eoc.	Strat.	Zagorodnyuk V. I. 1969
ex-Ussr General	Czc Mzc Pzc		Lipman R. Kh. 1976
ex-Ussr Kamtchatka			Runeva N. P. 1975
ex-Ussr Kamtchatka		Taxon. N.Sp.	Bailey J. W. 1856
ex-Ussr Kuban	Paleoc.-Eoc.	Taxon. N.Sp.	Borisenko N. N. 1960a
ex-Ussr Kuban	Eoc.	Taxon.	Borisenko N. N. 1960b
ex-Ussr Mid.Asia.	Czc Mzc		Tschedia D. M. 1984
ex-Ussr N.Sakhalin	Mioc.		Kozlova G. E. 1960
ex-Ussr NE.Azherbaidjan	Eoc.	Strat. Evolut.	Mamedov N. A. 1975
ex-Ussr Pacif.	Quater.		Strelkov A. A. & Reschetnyak V. V. 1971
ex-Ussr Paleoc. W.Kuban	Eoc.	Taxon. N.Sp.	Borisenko N. N. 1958
ex-Ussr Pre-Aral	Eoc.	Taxon. N.Sp	Lipman R. Kh. 1975a
ex-Ussr Pre-carpath.	Mioc.		Runeva N. P. 1969
ex-Ussr Pricaspian	Czc Eoc.	Strat.	Zagorodnyuk V. I. 1975
ex-Ussr Priscaspia.	Eoc.	Strat.	Nikitina I. P. & Zagorodnyuk V. I. 1981
ex-Ussr S.Sakalina W.Kamtchatka.	Mzc?		Runeva N. P. 1981
ex-Ussr Sakhalin	Neog.	N.Sp. Biostrat.	Popova I. M. 1988
ex-Ussr Shemakh.-Kobyst. Azerbaid.	Eoc.	Strat.	Mamedov N. A. 1973a
ex-Ussr Siberia	Czc Mzc		Lipman R. Kh. 1960
ex-Ussr Sikhote-Alinj			Eliseeva V. K. *et al.* 1976
ex-Ussr Tadjiksk.	Czc	Strat.	Goltman E. V. 1981a
ex-Ussr Tadzhiksk	Maastr.-Quater.		Goltman E. V. 1973
ex-Ussr Tadzhikski	Czc		Goltman E. V. 1971
ex-Ussr Tadzhikskoi		Strat.	Goltman E. V. 1975
ex-Ussr Tadzhikskoi	Quater.	Strat.	Goltman E. V. 1981b
ex-Ussr Turgay Pre-Aral.		Biogeog.	Lipman R. Kh. & Khokhlova A. I. 1964
ex-Ussr Turkmen.	Czc? Mzc?	Strat.	Moksyakova A. M. 1965
ex-Ussr Turkmen.	L.Eocene	Strat.	Moksyakova A. M. 1969
ex-Ussr Ukrain. Carpath.	Paleog.		Lozynyak P. Yu. 1985
ex-Ussr Urals		Skelet.	Amon E. & Kovaltchuk A. I. 1988
ex-Ussr W.Pre-Caucasus	Eoc.		Krasheninnikov V. A. 1960
ex-Ussr W.Siberian	L.Eoc.	Taxon. N.Sp.	Gorbovetz A. N. 1972
ex-Ussr W.Siberian	Paleog.-Recent	Biogeog.	Gorbovetz A. N. *et al.* 1972
ex-Ussr W.Siberian	L.Eocene		Kozlova G. E. & Gorbovets A. N. 1966

LOCATION	AGE	TOPIC	AUTHOR
ex-Ussr W.Turkmen.	L.Eocene		Moksyakova A. M. 1961
ex-USSR Crimea Tadzhiksk	Paleog. Eoc.		Chediya D. M. & Chediya I. O. 1973
ex-USSR N.Kamtchatka Bering S.	Paleog.		Averina G. Y. 1988
Faroe Channel	Quater.	Taxon.	Haeckel E. 1882
General	Quater.	Taxon.	Haeckel E. 1862
General	Czc-Quater.	Biol. Skelet.	Haeckel E. 1866
General	Mzc Czc	Taxon. Skelet.	Petrushevskaya M. G. 1979a
General	Mzc Pzc	Taxon.	Petrushevskaya M. G. 1984
General	Czc Mzc?		Zhamoida A. I. 1984
General		Taxon.	Riedel W. R. 1971b
General	Mzc Czc Quater.	Taxon.	Petrushevskaya M. G. 1975d
Global	Quater.	Ecol. Environ. Biogeog.	Casey R. E. 1977
Global	Czc Quater.	Biogeog. Ecol. Evolut.	Casey R. E. 1982
Global		Biogeog. Current Environ.	Casey R. E. *et al.* 1982
Indian	L.Eoc.	Taxon. Strat. Biogeog. Oc.	Goll R. M. & Caulet J. P. 1985
Indian Antarct.	Czc-Recent	Taxon. Plankt.	Petrushevskaya M. G. 1971c
Indian E.Arabia Peru	Mioc.-Recent	ODP	Caulet J. P. & Nigrini C. 1988
Indian Oc.	Neog.	Environ. Ecol. Season Current	Caulet J. P. 1977
Indian Oc.	Pleistocene	Biostr.	Caulet J. P. 1986
Indian Oc.	Neog.	Sedim. Environ.	Caulet J. P. 1978
Indian Oc.		Strat. Taxon. DSDP22	Johnson D. A. 1974a
Indian Oc.		Sedim. Mineral. Mn	Leclaire L. *et al.* 1976
Indian Oc.	Czc-Quater.	Taxon. Biogeog. Current Plankt.	Petrushevskaya M. G. 1973
Indian Oc. Antar.	Quater.	Taxon. Plankt.	Petrushevskaya M. G. 1977b
Indian Oc. Antar.		Taxon. Plankt.	Petrushevskaya M. G. 1971a
Indian Oc. Antar.	Quater.	Taxon. Plankt.	Petrushevskaya M. G. 1977a
Indian Oc. Antarctic	Quater.	Taxon. DSDP29	Petrushevskaya M. G. 1975c
Indian Oc. Atlant.		Plankt.	Nigrini C. A. 1967
Indian Oc. Indon. Burma Andama Isl.	Czc	Strat.	Jacob K. & Shrivastava R. N. 1952
Indian Oc. Pacif.Tropical	Neog.	Evolut. Strat.	Caulet J. P. & Nigrini C. 1988
Indian Oc.C.	Plioc. Quater.	Strat.	Caulet J. P. 1979
Indian Oc.E.	Quater.	Strat. Biogeog.	Johnson D. A. & Nigrini C. 1982
Indian Oc.S.	Paleoc.-Eocene		Caulet J. P. 1988
Indian Oc.S.	Neog.	Skelet. Ecol. Environ. Climat.	Granlund A. H. 1986
Indian Oc.S.	Quater.	Climat. Strat.	Caulet J. P. 1982
Indian Oc.S.	Neog.	Skelet. Environ. Ecol. Climat.	Granlund A. H. 1984
Indian Oc.S.		Taxon. Strat. DSDP26	Riedel W. R. & Sanfilippo A. 1974b
Indian Pacif.	L.Neog.-Quater.	N.Sp. Phylog.	Nigrini C. & Caulet J. P. 1988
Indian W.Gulf Aden		Taxon. Strat. DSDP24	Riedel W. R. & Sanfilippo A. 1974a
Indian.S.	Paleoc.	Ecol. Climat.	Morley J. J. 1989
Indian.W.	Neog.	Taxon. Strat. DSDP25	Sanfilippo A. & Riedel W. R. 1974b
Indian.W. Gulf Aden	Neog.	Taxon. Strat. DSDP24	Sanfilippo A. & Riedel W. R. 1974a
Indian.W. Oc.	Quater.	Biogeog.	Johnson D. A. & Nigrini C. 1980
Indian.W. Qc. Arabian Sea	Quater.	Strat. Taxon.	Nigrini C. A. 1974
Indian.W. Oc. E.Somaly Basin	Quater.	Sedim.	Caulet J. P. *et al.* 1988
Indonesia	Czc? Mzc?	Strat. Taxon.	Tan Sin-Hok 1931
Medit.	Czc	Taxon. N.Sp.	Haeckel E. 1861
Medit.	Czc	Taxon. N.Sp.	Haeckel E. 1860
Medit.	Czc-Quater.	Acanth.	Muller J. 1858
Medit.	Czc-Recent	Acanth.	Muller J. 1856
Medit.	Neog.	Taxon. Strat.	Sanfilippo A. *et al.* 1973
Medit.	Neog.	Taxon. Strat. DSDP42A	Sanfilippo A. *et al.* 1978

LOCATION	AGE	TOPIC	AUTHOR
Medit. Pacif.	Czc	Biogeog. Taxon.	Caulet J. P. 1971
Medit. Pacif. Amer.C. Carib. Gulf Mex.	Paleoc.-Neog.	Taxon. Strat. DSDP10	Sanfilippo A. & Riedel W. R. 1973
Medit. Pacif.W.	Neog.	Taxon. Strat.	Sanfilippo A. 1971
Medit. Tethys		Taxon.	Caulet J. P. 1974
Middle-East Israel	Eoc.		Reiss Z. 1952
Pacif.	Czc-Quater.	Sedim. Preserv.	Hurd J. D. 1973
Pacif.	Quater.	Preserv.	Hurd D. C. & Takehashi K. 1983
Pacif.	Czc	Strat. DSDP55	Koizumi I. *et al.* 1980
Pacif.	Czc-Quater.	Strat. Taxon. DSDP30	Holdsworth B. K. 1975
Pacif.	Plioc.-Quater.	Evolut. Taxon.	Kellogg D. E. 1976
Pacif.		Climat. Biozon.	Hays J. D. *et al.* 1972
Pacif.	Paleoc.Eoc.	Taxon. DSDP21 Strat.	Dumitrica P. 1973
Pacif.	Plio-Quater.	Strat. Climat.	Hays J. D. *et al.* 1969
Pacif.	Czc	Strat. Taxon.	Riedel W. R. & Funnell B. M. 1964
Pacif.	Mzc Czc	Strat. DSDP	Riedel W. R. 1981
Pacif.	Paleoc.-Eoc.	DSDP S.384	Nishimura A. 1986
Pacif.	Mioc.-Quater.	Strat.	Saito T. *et al.* 1975
Pacif.		DSDP56, 57	Reynolds R. A. et al. 1980
Pacif.	Mioc.	DSDP Strat.	Westberg M. J. & Riedel W. R. 1978
Pacif.	Czc-Quater.	Biogeog. Ecol. Climat.	Moore T. C. 1978
Pacif. Amer.C. Carib. Gulf Mex. Medit.	Paleoc.-Neog.	Taxon. Strat. DSDP10	Sanfilippo A. & Riedel W. R. 1973
Pacif. Amer.N. Calif.	Quater.	Strat. DSDP65	Benson R. N. 1983a
Pacif. Atlant. Antar.	Plioc.	Strat. Climat.	Keany J. 1976
Pacif. Australia		Sedim. Environ.	Fenton M. W. *et al.* 1982
Pacif. Australia		Sedim.	Hinde G. J. 1893
Pacif. Carib. Atlant.		Taxon. Evolut.	Goll R. M. 1968
Pacif. Carib. Atlant.		Taxon. Evolut.	Goll R. M. 1969a
Pacif. Equatorial		Strat.	Johnson D. A. & Parker F. L. 1972
Pacif. Equetorial	Quater.	Biogeog. Climat.	Johnson D. A. & Knoll A. H. 1974
Pacif. Indian Oc.	Paleog.	Environ.	Sancetta C. 1979
Pacif. Indones. Bangka	Czc Mzc	Sedim.	Hinde G. J. 1897
Pacif. Indones. Celebes			Hojnos R. 1934
Pacif. Indonesia Philippine Sea	Paleog.-Neog.	Biozon. DSDP59	Theyer F. & Lineberger P. 1981
Pacif. Mariana	Cret.-Czc-Quater.	Strat. DSDP60	Kling S. A. 1982
Pacif. Okhotsk Sea		Biogeog.	Kruglikova S. B. 1975
Pacif. Tahiti		Strat. Plankt.	Takayanagi Y. *et al.* 1982
Pacif. tropical	Czc	Strat. Taxon.	Friend J.K. & Riedel W. R. 1967
Pacif.C.		Sedim. Biogeog. Environ.	Leinen M. 1979
Pacif.C.	Quater.	Plankt. Sedim. Ecol. Biogeog. Preserv.	Renz G.W. 1976
Pacif.C. Equator.	Mioc.	Strat.	Blueford J. R. 1982
Pacif.C. Equatorial	Quater.	Environ. Sedim.	Blueford J. R. 1980
Pacif.C. Tropical	Quater.	Taxon. N.Sp.	Deflendre G. 1972
Pacif.Cent.	Quater.	Taxon. Plankt.	Petrushevskaya M. G. 1971b
Pacif.E.	Recent	Plankt. Oceano.	Boltovskoy D. & Jankilevich S. S. 1985
Pacif.E.	Quater.	Sedim.	Johnson D. A. 1974
Pacif.E.		Strat. DSDP16	Bukry D. *et al.* 1973
Pacif.E.	Plioc.-Quater.	Taxon. Strat. DSDP54	Goll R. M. 1980
Pacif.E.	Quater.	Environ. Current Strat.	Romine K. & Moore T. C. 1981
Pacif.E. Amer.C. Carib.	Neog.	Taxon. Strat. DSDP68	Riedel W. R. & Westberg J. M. 1982
Pacif.E. Amer.C. off Guatemala	Mioc.	DSDP67 Strat.	Westberg M. J. & Riedel W. R. 1982
Pacif.E. Amer.S. Peru	Czc-Quater.	Current Environ	Molina-Cruz A. 1984
Pacif.E. Calif. Peru	Recent	Plankt. Oceanol. Upwell. Ecol.	Pisias N. G. *et al.* 1986

LOCATION	AGE	TOPIC	AUTHOR
Pacif.E. off Peru	Mioc.-Quate	Stratig.	De Wever P. *et al.* 1995
Pacif.E. off Peru	Neog.	Strat.	De Wever P. *et al.* 1990
Pacif.E. Peru	Mioc.	Sedim. Environ.	Marty R. C. *et al.* 1987
Pacif.E. Peru E.Arabia	Mioc.-Recent	QDP	Caulet J. P. & Nigrini C. 1988
Pacif.E. Peru Nazca		Ecol. Current Environ. DSDP34	Sachs H. M. 1976
Pacif.E.tropic.		Plankt.	Nigrini C. A. 1968
Pacif.Equat.	Quater.	Strat. Plankt.	Nigrini C. A. 1971
Pacif.N. Bering Sea	Quater.		Ling H. Y *et al.* 1971
Pacif.N. SE.Bering	Quater. Recent	Sedim. Product.	Banahan S. & Goering J. J. 1986
Pacif.N.		Strat. Evolut.	Hays J. D. 1970
Pacif.N.	Mzc Quater.	Sedim. Preserv.	Erez J. *et al.* 1982
Pacif.N.	Czc	Biol. Sedim.	Kruglikova S. B. 1973
Pacif.N.		Ecol. Current Environ.	Sachs H. M. 1973
Pacif.N.	Quater.	Plankt.	Nigrini C. A. 1970
Pacif.N.		Taxon. Evolut. Skelet. Ecol.	Sachs H. M. & Hasson P. F. 1979
Pacif.N. (boreal-subtrop.)	Czc Quater.	Environ. Biogeog.	Kruglikova S. B. 1977
Pacif.N. Amer.C. Calif.	Neog.	DSDP63	Wolfart R. 1981
Pacif.N. Antar. Aflant.N.	Neog.		Lombari G. & Lazarus D. B. 1988
Pacif.N. Navarin Bering Sea	Quater.	Biogeog. Environ.	Blueford J. R. 1983
Pacif.N. S.Bering Sea	L.Czc	Diagen. Sedim.	Hein J. R. *et al.* 1978
Pacif.N.		Strat.	Quinterno P. & Theyer F. 1979
Pacif.N.Centr.	Recent	Ecol. Distrib.	Kling S. A. 1979
Pacit.NE.	Czc	DSDP18	Kling S. A. 1973
Pacif.NE.			Ling H. Y. 1966
Pacif.NE.	Quater.	Preserv.	Kadko D. *et al.* 1983
Pacif.NE.	Czc-Quater.	Current	Moore T. C. 1973b
Pacif.NE.	Recent	Sedim. Qceanog.	Yamauchi M. 1986
Pacif.NW.	Czc	Strat. DSDP55	Ling H. Y. 1980
Pacif.NW.		DSDP56	Sakai T. 1980
Pacit.NW.	Czc	DSDP56,57	Reynolds R. A. 1980
Pacif.NW.	Plioc.-Recent	Climat. Environ.	Morley J. J. 1987
Pacif.NW. Sea Okhotsk	Czc Quater.		Ling H. Y. 1974
Pacif.NW. Kamtchat. Kuroshio	Czc	Sedim. Current	Popova I. M. 1986
Pacif.S.	Mzc Czc	Plankt. Geogr.	Stevens 1980
Pacif.S.	Plioc.-Quater.		Lukanina I. V. 1985
Pacif.SE.	Quater.	Environ. Biogeog. Current Ecol.	Molina-Cruz A. 1977
Pacif.SE. Antar.	Czc	DSDP35	Weaver F. M. 1976
Pacif.Tropic. Indo.	Neog.	Strat.	Johnson D. A. *et al.* 1987
Pacif.W Saipan Mariana	Eoc.	Strat.	Riedel W. R. 1957b
Pacif.W Tropical	Oligoc.-Mioc.	Taxon.	Riedel W. R. 1959
Pacif.W.		Taxon. Strat. DSDP7	Riedel W. R. & Sanfilippo A. 1971
Pacif.W.	Czc	Strat. DSDP61	De Wever P. 1981
Pacif.W.	Quat	Biogeog. Paleocean. Sedim.	Boltovskoy D. 1987
Pacif.W.	Czc	Taxon.	Riedel W. R. 1952
Pacif.W. Philip. Indian Oc. Indon. Pacit.		DSDP58	Sloan J. 1980
Pacif.W.	Paleog.-Quater.	Strat.	Sanfilippo A. *et al.* 1981
Pacif.W.Centr.Equat.		Biozon.	Kobayashi K. *et al.* 1971
Pacif.W.C. Taiwan	Czc Recent	Sedim.	Cheng Y.-N. & Yeh K.-Y. 1989
Pacific		Sedim. Qceanol. Miner.	Baker E. T. *et al.* 1979
Pacific	Neog.	Earth rotation	Hammond R. S. *et al.* 1979
Pacific Antar.S.	Quater.	Skelet.	Boltovskoy D. & Vrba A. 1989
Pacific Centr.		DSDP33 Strat.	Johnson D. A. 1976

LOCATION	AGE	TOPIC	AUTHOR
Pacific Equat.	Mid.Mioc.	Strat. Biozon.	Johnson D. A. & Wick B. J. 1982
Pacific Indian Oc.	Neog.	Environ.	Sancetta C. 1978
Pacific Equat.	Quater.	Sedim. Current Ecol. Environ. Skelet.	Takahashi K. & Ling H. Y. 1980
Pacific Equatorial	Quater.	Strat. Biozon.	Johnson D. A. & Knoll A. H. 1975
Red Sea		Season Environ. Biogeog.	Goll R. M. 1969b
Ross Sea	Neog.	Climat. DSDP 274	Robert C. *et al.* 1988
Sicily	E.Plioc.	Taxon. Strat. DSDP	Riedel W. R. & Sanfilippo A. 1978b
Tethys	Czc	Taxon. N.Sp. Evolut.	Dumitrica P. 1983a
Tethys Alps Carpath. Klippen			Hojnos R. 1929
Tethys Carpat. Romania	Mioc. (Torton.)		Dumitrica P. 1968
Tethys Carpath.	Mioc.		Dumitrica P. *et al.* 1975
Tethys Cyprus.	Cret.-Czc	Strat. Environ.	Robertson A. H. F. & Hudson J. D. 1974
Tethys Europe Cyprus	Paleoc.-Eoc.	Biozon.	Khokhlova L. I. E. 1988
Tethys Europe Italy	Mioc.(Torton./ Messin.)-Plioc.	Strat.	Coalongo M. L. *et al.*1979
Tethys Europe Italy	Mioc.	Taxon. N.Sp.	Carnevale P. 1908
Tethys Europe Italy	Mzc Czc	Taxon. N.Sp.	Vinassa de Regny P. E. 1898
Tethys Europe Italy	Czc	Taxon.	Neviani A. 1901
Tethys Europe Italy	Mioc.		Vinassa de Regny P. E. 1900
Tethys Europe Italy Calabria	Czc	Strat.	Seguenza G. 1880
Tethys Europe Italy Napoli Messina	Czc Quater.	Biol.	Cienkowski L. 1871
Tethys Europe Italy Rotti	Czc	Strat. Taxon.	Riedel W. R. 1953
Tethys Europe Italy Sicilia (Tripoli)	Mioc.	Taxon. Strat.	Cocco L. 1905
Tethys Europe Italy Sicily	Mioc.	Taxon.	Dreyer F. 1890
Tethys Europe Paratethys	Mioc.	Environ. Crisis DSDP42	Rogl F. *et al.* 1978
Tethys Europe Slovakia	Mioc.(Badenian)	Taxon. Strat.	Dumitrica P. 1978
Tethys Europe Spain	Mioc.	Environ.	Berggren W. A. *et al.* 1976
Tethys Europe Switzerl.	Mzc Czc	Taxon.	Jaccard F. 1909
Tethys Medit.	Quater.	Environ. Preserv. Anoxia	Bjørklund K. R. & De Ruiter R. 1987
Tethys Oman			Hudson R. G. *et al.* 1954
Tropic.Pacif.	Neog.	Evolut.	Levykina I. E. 1985
Tropical	Recent	Sedim. Preserv. Ecol.	Takahashi K. 1981
Tropical	Recent	Plankt. Sedim.	Takahashi K. 1982
Tropical Pacif.	Mioc.-Quater.	Taxon. Plankt.	Nigrini C. A. 1977
Valdivia	Quater.	Taxon. N.Sp. Biogeog. Skelet.	Haecker V. 1907
W.Norway Fjord	Quater.	Sedim. Environ.	Aarseth I. B. *et al.* 1975
World	Czc Mzc		Premoli-Silva I. *et al.* 1976
World Ocean.		Taxon. Skelet.	Petrushevskaya M. G. 1981b
Zealand SE.Otago		New sp.	Benson W. N. & Chapman F. 1938

TABLE 2. — List of publications dealing with Cenozoic strata of the Russian platform. Each publication has a number which corresponds to that on figures 6-14. For each publication the age, region, longitude and latitude, subject of investigation, paleoenvironment and other involved fossil groups is given.

Author	Age	Region	Longitude Latitude	Subject of investigation	Paleoenvironment	Other fossils
1 Amon & Kovaltchuk 1988	Pg Paleocene Eocene	Eastern Ural Turgay	62°30´1-65°00´1E 48°00´1-50°00´1N	Radiolarian zonation established by Lipman for Talitskaya, Serovskaya & Irbitskaya formations.	Talitskaya formation (Paleocene): recrystallized association of Radiolaria, Serovskaya formation (Late Eoc.) shallow water association, Irbitskaya formation (Mid.-Up. Eoc.) pelagic association.	no data
2 Borisenko 1958	Pg Paleocene	Western Kuban Northern Caucasus 1) Beslineevsko-Shedok region 2) Abinsk region (Goryachiy Klyuch) 3) Seversky district (balka Kipashaya)	1) 40°00´1-41°00´1E 44°00´1-45°00´1N 2) 38°30´1-39°30´1E 44°00´1-45°00´1N 3) 38°00-38°30´1E 48°50´1-49°00´1N	Radiolaria from Ilskaya and Psekupskaya formations. 40 new taxa described	Shallow water association	no data
3 Borisenko 1960b	Pg Upper Paleocene	Eastern Kuban 1) Cossak village (boundary between Azovsky and Krasnodarsky district) 2) river M. Zelenchuk (Stavropolsky district)	1) 37°30´1-40°00´1E 46°15´1-47°30´1N 2) 42°00´1-42°30´1E 43°30´1-44°00´1N	Radiolaria from Abasinskaya formation 10 new taxa described	Shallow water association	no data
4 Borisenko 1960a	Pg Lower-Middle Eocene	Western Kuban 1) Babakov George (trubutary of r. Psekups), 2) district Kipuashaya (Gluboky jar) 3) r. Shebsha-Shibika interflow	1) 38°30´1-39°00´1E 44°00´1-45°00´1N 2) 38°00´1-38°30´1E 48°50´1-49°00´1N 3) not found	Radiolaria from Zubzinskaya, Kutaisskaya, Kaluga formations. 15 new taxa described	Shallow water association	no data

5 Chediya Kreidenkov Ashurov 1971	Pg Paleocene	South-eastern Middle Asia 1) Mountain range Peter 1st 2) Khodzha-Kasian 3) Aryk-Tau 4) Istum-Tay 5) Kichik-Donguz	1) not found 2) Khodzha: 70°58´E 40°45´N 3) not found 4) not found 5) not found	Paleocene Radiolaria from Bukharsk layers	Pelagic association	Pelecypods gastropods brachiopods foraminifers ostracods corals
6 Chediya 1973	Pg Eocene	A- Mid.Asia 1) south-western spurs of the Gissarsk mount range 2) Tadzhiksk depression 3) Fergana B- E.Turkmenia 1) Bukharo-Khiva depression	A- 1) 67°35´-67°45´E 37°30´-37°40´N 2) no precise data 3) 71°19´E;40°23´N B- 1) 60°30´-65°00´E 40°00´-41°00´N	Eocene Radiolari, are studied in thin sections from deposits of Kuberlinsk, Kerestinsk & Kumsk horizons	no data	Radiolaria in rocks analogues to *Globorotalia aequa*, *G. sububotinae* *Globigerina aragonensis* etc. forams's zones
7 Chediya D. M. & Chediya I. O. 1973	Pg Late Paleocene- Early Eocene	Crimea Bakhchisaray strato-type section (Simferopol region)	33°00´-33°30´E 44°30´-44°45´N	Radiolaria (bad preserv.) from Kashinskaya formation (Late Paleocene) and Bakhchisaraisky horizon (Early Eocene), no description.	Shallow water association	no data
8 Chediya 1981	Pg Early Eocene Middle Eocene Late Eocene	Middle Asia 1) E. Turkmenia (Bukharo-Khivinsk depression), SE of Mid. Asia (SW spurs of Gissarsk mountain ranges), Tadzhiksk depression and Fergana 2) Simferopolsky region	1) 64°00´-66°00´E 38°00´-40°00´N 2) 33°00´-33°30´E 44°30´-44°45´N	Radiolaria from 1. Kachinsky, 2. Bakhchisaraisky, 3. Alminsky, 4. Simferopolsky, 5 Bodraksky formations of Simferopolsky region and 1. Suzaksk, 2. Alaisk, 3. Turkestanian, 4. Rishtansk, 5. Isfarinsk horizons of Middle Asia	Alternation of shallow and deep water associations in Simferopolsky region and shallow water associations in Middle Asia	Foram's associations 1. *Acarinia acarinata* 2. *Operculina semirvolita* 3. *Globigerapsis* index zones
9 Gorbunov 1971	Jurassic Cretaceous Paleogene Neogene	Ukraine 1) Kiev (Koryukovka v.) provinces 2) Chernigov (Kholmy v.) prov.	1) 32°10´-32°20´E 51°15´-51°30´N 2) 32°30´-32°40´E 51°45´-51°50´N	Radiolarians of Jurassic, Cretaceous, Paleogene and Neogene summary of the history of the investigations, no description or plate.	no data	no data

Author	Age	Region	Longitude Latitude	Subject of investigation	Paleoenvironment	Other fossils
		3) Poltava (Volynsk) provinces 4) Odessa (Khollodny v.) provinces	3) 34°00´-35°00´E 49°00´-50°00´N 4) 30°30´-31°00´E 46°30´-47°00´N			
10 Kestner 1971	Pg Eocene	Middle Asia, Bukharo-Khivinsk depression (1-5) and SW spurs of the Gissarsk mountain range (6-7) 1) Kushab 2) Khatar 3) Pamuk 4) Lakkent 5) Razak 6) Dekhanobad 7) Toichisai	1) no precise data 2) not found 3) not found 4) not found 5) territory between Khiva (60°49´E;41°25´N) and Bukhara (64°26´E;39°47´N) 6) 66°30´E;38°24´N 7) no precise data	Eocene Radiolaria from Beloglinsk, Kuberlinsk, Kerestinsk horizons	Pelagic association in Upper Eocene shallow water in Lower Eocene	E. Eocene: *Globorotalia-aequa* + *G. subbotina*. M. Eocene: *Globorotalia aragonensis*, *Acarinina crassaformis*. L. Eocene: *Acarinina rotundimarginata*.
11 Kestner 1973 a	Pg Oligocene	Ust Yurt Aidzhankos area, Barsakeljmesskij trough	no precise data	Oligocene Radiolaria	Shallow water association	L. Eocene *Lenticulina hermanni* + Oligocene *Bolivina antegreassa*
12 Kozlova 1984a	Pg Upper Paleocene Lower Eocene	Middle Povolshie, Eastern Ural. Western Siberia 1) Syzran 2) Sengiley 3) Oulianovsk 4) Korshevka 5) Insa	1) 48° 25´-48° 30´E 53° 15´-53° 20´N 2) 48° 45´-48° 48´E 53° 50´-53° 57´N 3) 48° 22´-48° 25´E 54° 19´-54° 20´N 4) 48° 10´-48° 15´E 54° 15´-54° 10´N 5) 46° 20´-46° 21´E 53 °50´-53° 51´N	9 radiolarian assemblages are given, 7 rad zones established in different formations from Povolshie, E. Ural W. Siberia 4 n. sp. are described	Alternation of shallow and deep water associations of Radiolaria	L. Paleocene diatoms zones:1) *Trinacria herbergiana*, 2) *Trinacria ventriculosa* 3) *Coscinodiscus uralensis* Early Eoc. Z.: 1) *Coscinodiscus payeri*, 2) *Pyxilla gracilis*
13 Kozlova 1990	Pg Upper Paleocene Lower,	Pre-Caspian region 1) Miyalinskaya-r.Uil v. Miyaly 2) Kamiskolskaya	1) 53° 56´E; 48° 55´N 2) 53° 00´-53° 30´E 48° 30´-49° 30´N	Phylogeny and description of *Axoprunum*, *Heliodiscus*, *Tripodiscinus*, *Clathrocyclas*, *Lychnocanum*	no data	no data

	Middle, Upper Eocene	(near Akshatau(?)) 3) Lybenka Voronesh anticline 4) Kantemirovka 5) River Don bassin	3) 54° 13´E; 50° 22´N 4) 39° 52´E 49° 40´N 5) no precise data	& *Phormocyrtis* of Eocene-Upper Paleocene deposits is given The biozonation for boreal province is introduced		
14 Kozlova 1993	Pg Upper Paleocene Lower, Middle, Upper Eocene	1- 9) Voronesh anticline 10- 19) Middle Povolshie 20- 28) Eastern Ural 29- 34) Pre-Caspian 58- 60) W.Siberia 1) Russkie Tishki 2)+3) River Oskol 4) Deresovka 5) Kantemirovka 6) Nikolskoe (near Kalach) 7) Baltinovsk 8) Vorobjevka (n.Vorontsovka) 9) River Mishkova (near Meshkovskaya) 10) Dzhanybek 11) Korshevka 12) Sengiley 13) Insa 14) Balashejka (near Barysh-Kuzovatovo) 15) Kuznetsk 16) Suchanovka 17) Kiselevka+18.r. Alaj +19.Djupa 29) North Emba 30) Emba 31) South Emba 32) Temir 33) Irgiz 34) West Kazachstan, well 125 58) +59) 60) Uspenskaya well	1) 36°44´E;49°51´N 2) 36°44´-37°30´E 49°51´-49°30´N 3) + 4) not found 5) 39°52´E;49°40´N 6) 41°15´-41°80´E 50°10´-50°20´N 7) not found 8) 33°49´E;45°51´N 9) 42°00´-42°10´E 49°40´-49°50´N 10) 46°50´E;49°25´N 11) 12) 13) : =2) 4) 5) 14) 47°09´E;53°40´N 15) 46°35´E;53°08´N 16) see Syzran n°1 17) 18) 19) : 45°00´-47°30´E 52°00´-52°30´N 29) +30) +31) : 54°30´-57°30´E 47°00´-49°00´N 32) 57°06´E;49°09´N 33) 61°14´E;48°36´N 34) 62°30´-65°00´E 47 30´-48 00´N 58) + 59) see loc. n°2, 3 in Kozlova 1984 loc.n°12) 60) no precise location 55°00´-57°00´E 48°30´-49°00´N	Radiolaria of boreal province The scheme of Upper Paleocene Eocene Radiolarian zones correlation is given for North Caspian Sea, River Don, River Volga middle flow, East Ural slope Western Siberia	no data	Correlation of zonal subdivision based on radiolaria, planctonic, foraminifera, nannoplankton and dinoflagellates is given

Author	Age	Region	Longitude Latitude	Subject of investigation	Paleoenvironment	Other fossils
15 Krasheninnikov 1960	Pg Lower, Middle, Upper Eocene	Pre-Caucasus west 1) Moldavano-Psifsk 2) Zybsinsk erea 3) revine Kipyachaya 4) ravine Solenaya	1) no precise data 2) no precise data 3) no precise data 4) 42° 25´-42° 30´E 46°15´-46° 30´N	42 new species and 2 new genera are described	Shallow water association	Early Eocene foraminifera zones *Globorotalia subbotinae* Low-Middle Eocene and Mid. Eocene Rad's assemblages are discovered within foraminifera's zone *Globorotalia aragonensis*
16 Lipman 1950	Pg Eocene	Turkestan, central Kyzyl-Kum: 1) Temdy 2) Shchulj trough 3) Chetyr well 4) W. slope of the Tamdinsk stage W. Kyzyl-Kum 5) Dzhankoi 6) Ak-Oi 7) Usun-Kuduk, S.-W. Kyzyl-Kum	1) Tamdybulak(?) 64°36´E;41°46´N 2), 3) not found 4) Tamdytaul(?) 63°20´-63°30´E 41°15´-41°25´N 5) 34°20´E 45°40´N 6) not found 7) not found	18 new taxa described in Eocene association of Radiolaria	Shallow water association	no data
17 Lipman 1965	Cr Maestrichtian Danian Pg Paleocene Eocene	SE & W Turkmenia Turgai, Northern Pre-Aral 1) Kustanai 2) Semiozernoe 3) Saksayl'sk 4) Mis Izyndy-Aral 5) Baikonur 6) river Turgai (middle flow) 7) Aralsk 8) Kushmurun 9) Semiozernoe 10) Amangel'dy 11) Chelkar 12) Togyz 13) Mountains	1) 63°40'E 53°15'N 2) 64°06´E 52°22´N 3) 61°06´E 46°07'N 4) 59°29´E 45°48'N 5) 66°03´E 47°50´N 6+15) 60°12´E 48°49´N 7) 61°43´E 46°56´N 8) 64°37´E 52°30´N 9) 64°06´E 52°22´N	1) The distribution of 98 species is given in the Eocene deposits 2) Two zonal subdivisions based on Radiolaria are established a) *Spongurus biconstrictus* b) *Ellipsoxiphus chabakovi* in Tasaransk series	Alternation of deep water and shallow water Radiolarian association	*Spongurus biconstrictus* association occurs together with foraminifera *Nummulites distans* *N. murchissoni* etc. *Ellipsoxiphus chabakovi* association of Radiolaria occurs together

		Tas-Aran 14) Tshchebas gulf 15) Aktogai 16) Irgiz 17) Turgai	10) 65°11´E 50°12´N 11) 59°39´E;47°48´N 12) 60°32´E;47°32´N 13) 59°20´-59°40´E 46°15´-46°20´N 14) 59°40´-59°45´E 46°05´-46°10´N 16) 61°14´E 48°36´N 17) 63°25´E 49° 38´N			with foraminifera *Speroplectammina* *spectabilis*
18 Lipman 1976	Pg Paleocene Eocene Cr Maestri- chtian, Danian	Northern Pre-Aral Turgaisk Trough 1) Mount Tas-Aran 2) Chagrayskoye Plateau 3) Chelkar village 4) Lake Tebes 5) Tumaly-Kolj vil. 6) Turgai village 7) Saksaulskiy 8) Belgorod 9) Astrakhan 10) Krasnovodskoe pl. 11) Kustanai 12) Emba 13) Bukhara (region) 14) Chardzou (?) Komsomolsk (between Ashkhabad and Bukhara)	1) not found 2) 57°30´-58°30´E 45°45´-47°00´N 3) 59°39´E 47°48´N 4) not found 5) not found 6) 63°25´E 49°38´N 7) 61°06´E;47°06´N 8) 36°36´E;50°38´N 9) 45°30´-46°30´E 46°00´-47°00´N 10) 52°35´-52°40´E 40°10´-40°15´N 11) 62°30´E 52°25´-52°35´N 12) 54°30´-57°30´E 47°00´-49°00´N 13) 64°10´-64°30´E 39°20´-39°30´N 14) 63°34´E;39°01´N	The map with *Conocaryomma* *aralensis* occurrences is given	no data	no data
19 Lipman 1969	Pg Eocene	Turgaisk Trough, Northern Pre-Aral	locations are the same as in Lipman 1965	New Family-Conosphae- ridae, new subfamily Conocaryomminae, new genus *Conocaryomma* and 2 new species *C. aralensis*, *C. lentis*	no data	no data

Author	Age	Region	Longitude Latitude	Subject of investigation	Paleoenvironment	Other fossils
20 Lipman 1972	Pg Eocene	Turgaisk Trough, Northern Pre-Aral	all location from Lipman 1965	11 new species and 11 new genus are described	Shallow water association	no data
21 Lipman 1975a	Pg Middle Eocene	Northern Pre-Aralie 1) Izyndy-Aral	1) 59°29´E 45°48´N	4 new species of Radiolaria are introduced	Shallow water association	Nummulites + Foraminifera
22 Lipman 1982	Pg Oligocene	Northern Pre-Black Sea 1) Lower Serogozsky region of Khersonsky district	1) 32°00´-32°30´E 46°25´-46°50´N	2 new species of Radiolaria are described	Shallow water association	Foraminifera + mollusc fauna
23 Lipman 1984a	Pg Paleocene Eocene Oligocene	North Western Caucasus and Apsheron peninsula		Correlation of the stratigraphical division of the Paleocene and Eocene stages based on Radiolarians and Fora minifera	Shallow water association	Foraminifera scale is provided
24 Lipman 1984b	Pg Upper Paleocene	Crimea, Bakhchisaray area 1) Bakhchisaray (v. Sfaroselie) 2) r. Kacha (v. Predushelnoe) 3) SuvluKaja Mount. 4) r. Belbek (near Bakhchisaray) 5) Bakhchisaray (quarry of cement's factory) 6) Kizil-Djar Mountain (v. Pochtovoe)	1) 33°53´E 44°44´N 2) 33°50´-34°10´E 44°30´-44°40´N 3) not found	Pg Radiolaria, conclusion: impossible to compare rad's associations of Crimea and Middle Asia. No Radiolaria record have been found in the sections of r. Belbek, cement quarry near Bakhchisarai, m. Kizil-Djar (near v. Pochtovoe) and v. Staroselie	Shallow water association	Foraminifera scale is provided
25 Lipman 1993	Pg Paleocene Oligocene Eocene	North Eurasia	no precise data	Radiolarian zonation for the North Eurasia is provided and correlated with the rad's zonation suggested by Sanfilippo,	no data	Correlation with foraminifera's

				Westberg & Riedel, 1981 for the Paleogene deposits of the oceans tropical realm		and nannoplankton's zonation is made
26 Lozyniak 1985	Pg Eocene, Oligocene	Ukranian Carpatians Skybe zone 1) river Cheremosh 2) r. Prut 3) r. Stryy 4) r. Dnestr	1) 25°00´-25°30´E 48°10´-48°30´N 2) 25°00´-26°00´E 48°30´-48°35´N 3) 23°30´-24°00´E 49°10´-49°30´N 4) 24°10´-24°30´E 49°20´-49°40´N	Poor to moderate preserved radiolarian associations have been studied	no data	no data
27 Mamedov 1969a	Pg Eocene	Azerbaidjan 1) Shemakhino-Kubastanskaya area 2) Apsheronian peninsula area	1) 48°25´-48°30´E 40°30´-41°30´N 2) 49°30´-50°30´E 40°10´-40°40´N	6 new radiolarian species are described	no data	*Globorotali crassaformis, Globiger inoita* index, *Globigerina turkmenika, Globorotalia aragonensis*
28 Mamedov 1969b	Pg Eocene	Azerbaidjan 1) South-Eastern Caucasus a- Shemakhino-Ismaiitinsky, b- Kubastan 2) Apsheronian peninsula	1) a- 48°37´E 40°38´N Shemakha 48°10´E;40°46´N Ismailly, b- 48°33´E;41°23´N Kubastan 2) 49°30´-50°30´E 40°10´-40°40´N	6 new radiolarian species are described	no data	no data
29 Mamedov 1969c	Pg Eocene	Azerbaidjan 1) Sumgait river	1) 48°45´-49°30´E 40°30´-40°50´N	6 new radiolarian species are described	no data	no data
30 Mamedov 1970	Pg Middle Eocene	Azerbaidjan North-East part 1) village Kirovka	1) not found	6 new radiolarian species are described from deposits of Low. Coun formation	no data	no data
31 Mamedov 1973a	Pg Up. Paleocene Low., Mid., Up. Eocene	Azerbaidjan all locations of the samples are from previous publications	1), 2) see Mamedov 1969b 3-7) no precise data	5 new radiolarian species are described	no data	*Globorotalia crassaformis*

Author	Age	Region	Longitude Latitude	Subject of investigation	Paleoenvironment	Other fossils
32 Mamedov 1973b	Pg Eocene	Azerbaidjan 1) Shemakhinskaya area 2) Ismaillinskaya area 3) Kirovka village 4) Agdara 5) Gadshili 6) Khiljmili 7) Dijally	1), 2) see loc. n° 28 3-7) not found	5 radiolarian associative zones are established in Sumgaitskaya and Low., Mid., Up. Coun formations and correlated with 6 Foraminiferal biostratigraphical zonation	no data	8 biostratigraphical subdivisions based on foraminifera's data
33 Mamedov 1975	Pg Lower Middle Upper Eocene	Azerbaidjan	All locations are from previous publications	3 stages in the development of Eocene Radiolarians are given 1- Early Eocene, 2- Mid. Eocene, 3 - Late Eocene	no data	First stage coincides with *Globorotalia subotinae* Second stage with *Globorotalia crassaformis* Third stage with Globigerinoita index
34 Mamedova. Mamedov 1970	Pg	Azerbaidjan 1) Gadzili village 2) Shemakhinsk area	no precise data	Plates with the age, lithology and Radiolarian assemblages are provided	no data	Correlation with foraminifera data is made
35 Moksyakova 1961	Pg Upper Eocene	Western Turkmenia 1) Southern Usl-Yurt 2) Malii and Bolshoi Balkhan 3) Koimat-Dag 4) Krasnovodskoe plateau 5) Usboisk corridor 6) Erbent Tashaus (Central Karakums)	1) not found 2) 54°30'-54°50'E 39°10'-39°30'N 3) not found 4) 52°30'-53°00'E 40°10'-40°20'N 5) 55°00'-55°30'E 39°00'-39°20'N 6) 59°58'E;41°49'N	18 new species of Radiolaria are described from Kumsky horizon	Deep water association alternating with shallow water association	no data
36 Moksyakova 1965	Pg Upper Eocene	Turkmenia 1) hole 304 (Kara-Bogaz-Gol gulf) (N-W bay) 2) exp.5 [Kara-Bogaz-Gol gulf] (south part Omchali)	1) 52°55'-52°57'E 41°10'-41°15'N 2) 53°44'E 40°38'N 3) 53°45'-53°50'E 40°05'-40°10'N 4) 59°07'E	10 new radiolarian species are described from Kerestinsky and Kyberlinsky horizons	Deep water association of Radiolaria	no data

		3) hole 3 (150 km to the west from Krasnovodsk) 4) Nukus 5) Tashauz 6) Darvaza 7) Sernyy Zavod 8) Chardzhou 9) hole 35	42°28´N 5) 59°58´E 41°49´N 6) 58°24´E 40°12´N 7) 58°18´E 40°00´N 8) 63°34´E;39°09´N 9) 63°00´-63°10´E 37°30´-37°40´N			
37 Nikitina, Zagorodnyuk 1981	Pg Eocene	1) Lower Don bassin 2) Northern Pre Caspian (rivers Sagiz· Emba) 3) Ergen-eastern Pre-Azov (western part of Karpinsky swell)	1) 40°00´-41°00´E 47°00´-48°00´N 2) Emba (see loc n° 18) 50°00´-55°00´E 47°30´-48°30´N 3) 37°30´-40°00´E 45°00´-47°30´N	Eocene Radiolaria and Foraminifera, 1) Range-charts of Eocene benthic foraminifera from South Sagiz - Eastern Part of Russky platform and Scifsky plate is given, 2) Correlation of radiolarian and foraminiferal biostratigraphic zones is made	Plate illustrates shallow water-radiolarians and foramini feras associations	Zonation based on Foraminifera data is give
38 Radionova Khokhlova 1994	Pg Up.Paleocene formations Goryachii Klyuch, and Abaza Lower Eocene Formations: Cherkess, Zybza, Kutaisi (r. Belaya) Mid. Eocene Formations: Kaluga and Khadyzhensk (western Kuban) Oligocene Khadsum horizon of the Maikop Group	A- Crimea 1) Eupatoria 2) Nasypnoe B- Caucasus 3) Anapa C- Western Ukraina 4) Shibik river 5) Glubokii Yar 6) Balka Kipyach'ya 7) Balka Glubokaya 8) Pshish river 9) Kurdzhips river 10) Laba r. 11) Belaya r. 12) Kuban r. 13) Kheu r. 14) Urukh r. 15) Rubas-Chai r. 16) northern Kobystan (15,16) western part of Caspian Sea 17) Karagie depression 18) Bol'shoi Balkhan mountains	1) 33°20´E;45°12´N 2) near Feodosiya, no precise data 35°23´E;45°03´N 3) 37°20´E;44°54 N 4) 100-200 km S of Novor ossiysk 37°46´E;44°44´N no precise data 5) no precise data 6) no precise data 7) no precise data 8) near Goryachi Klyuch, 39°18´E;44°36´N 9) no precise data 40°44´E;44°39´N 10) near Labinsk and Shedok 40°50´E;44°13´N; 11-17) no precise data 18) 55°30´-55°20´E 39°00´-39°20´N	a) Nannoplankton and foraminifera's biostratigraphy. b) Paleogene episodes of biogenic silica accumulation correlated with transgressive-regressive cycles. c) The list of Radiolarian taxa, found in Up. Paleocene-Low. and Mid. Eocene and Oligocene deposits is provided	Radiolarian as semblages are of shallow-water origin except Mid.Eocene association discovered in Dagestan (Rubas-Chai r.)	Nanno-plancton foraminifera silicoflagellates, diatom

Author	Age	Region	Longitude Latitude	Subject of investigation	Paleoenvironment	Other fossils
39 Runeva 1969	Neogene Miocene	Pre Carpatian 1) Kalush-Zoljnyi zone 2) Vyrva r. 3) Banevichi v. 4) Tarnavka r.	1) 24°20'E;49°02'N (Kalush) 2) no precise data 3) no precise data 4) no precise data	Lower Miocene generic composition of the radiolarian association from Verbovetsk layers of Vorotyshchensky series is provided	no data	no data
40 Subbotina 1960	Paleogene Neogene Oligocene Lower Miocene Zagorsky series	Pre Carpatians, East Carpatians 1) Vorotyshche r. Pollanitsky, Vorotyshchensky, 2) Slonitsa r. 3) Tysmenitsa r.	1) 23°31'E;49°16'N 2) no precise data 3) no precise data (near city Truskavets)	6 radiolarian taxa were found. Preservation is very poor. Redeposition	no data	Oligocene *Globo rotalia denseconnexa subbotinae, Globigerina pseudoedita* Miocene redeposition of Foraminifera has been observed.
41 Tochilina 1969	Pg Upper Paleocene, Lower Middle Upper Eocene	Voronesh anticline 1) Russkaya Zhuravka v, 2) Eryshevka v. 3) Semenovka v. 4) Gavrilinsk 5) Pavlovsk	1) 40°35';50°21'N 2) no precise data 3) no precise data 4) no precise data 5) 40°07'E;50°28'N	Early, Middle, Late Eocene radiolarian associations are given, no Radiolaria in Oligocene sediments	no data	no data
42 Tochilina 1975	Pg Upper Paleocene Lower Eocene Middle Eocene Upper Eocene	Voronesh anticline 1) territory within square; Rossosh v.- Losevo v.-Kalach-Boguchar v. 2) near Chuguev v. 3) near Belgorod v. 4) near Obojan v. 5) near Kantemirovka v. 6) near Veshenskaya v	1) Rossosh-39°35'E 50°12'N Losevo- 40°02'E 50°41'N Kalach- 41°02'E 50°26'N Boguchar- 40°34'E 49°58'N 2) 36°44'E;49°51'N 3) Belgorod 4) no precise data 36°36'E;50°38'N 5) 39°52'E 49°40'N 6) 41°45'E;49°39'N	Up. Paleocene (Sumskaya form.) Low. Eocene (Kanevskaya f.) M. Eocene (Kievskaya form.), Up. Eocene (Kharkovskaya formation) Three periods of radiolarian fauna development are established I- Late Paleocene-Early Eocene II- Late Eocene-Kievsky III- Late Eocene-Kharkovsky	Alternation of shallow and deep water radiolarian associations	Up. Paleocene alternation of radiolaria & Molluscs bearing deposits Low. Eocene Radiolarians with Foraminifera Mid. Eocene Radiolarians. with Foraminifera & Molluscs Up. Eocene alternations of Molluscs & and Rad.' bearing deposits

43 Zagorodnyuk 1969	Pg Upper Eocene	Russian platform 1) Lower flow of the Don river Pre-Caspian lowland 2) the bassin of the Northern Emba Azovo-Kubansk through and 3) Azov elevation a- Sal'sk b- Alexandrovskoe c- Kanevskaya d- Rostovskaya 4) Salo-Manych inter-fluve a- r. Manych b- western Ergen (Ulan Erge)	1) 40°00´-41°00´E 47°30´-47°45´N 2) see loc n°14 3) a- Sal'sk- 41°33´E;46°30´N b- Alexandrovskoe (Stavropol)- 42°59´E;44°45´N c- 38°57´E;46°05´N d- 39°45´E;47°15´N 4) (North Pre-Caspian) a- 40°10´-40°40´E 47°10´-47°00´N b- 44°52´E;46°17´N	3 different Radiolarian associations for the Lower Don river flow and 4 assemblages for Northern Emba (Pre-Caspian) have been described Kuberlinsk, Kerestinsk, Kumsk and Beloglinsk layers from Emba and (Northern Pre-Aral) Tasaranskaya, Saksaylskaya, Cheganskaya	Deep-water and shallow water Radiolarian association	no data
44 Zagorodnyuk 1975a	Pg Eocene	Russian platform Lower flow of the Don river	no precise data	Peculiarities of the morphological structure of some Sphaeroidea and Discoidea	no data	no data
45 Zagorodnyuk 1981	Pg Mid.,Up. Eocene boundary	1) South-Eastern part part of Russian platform 2) Eastern Pre-Caspian	no precise data	The taxonomical composition of radiolarian assemblages from Bakhchisaraisky and Simferopolsky layer is described	Shallow water radiolarian associations	correlation with biostratigraphical zonation based on foraminifers data is provided

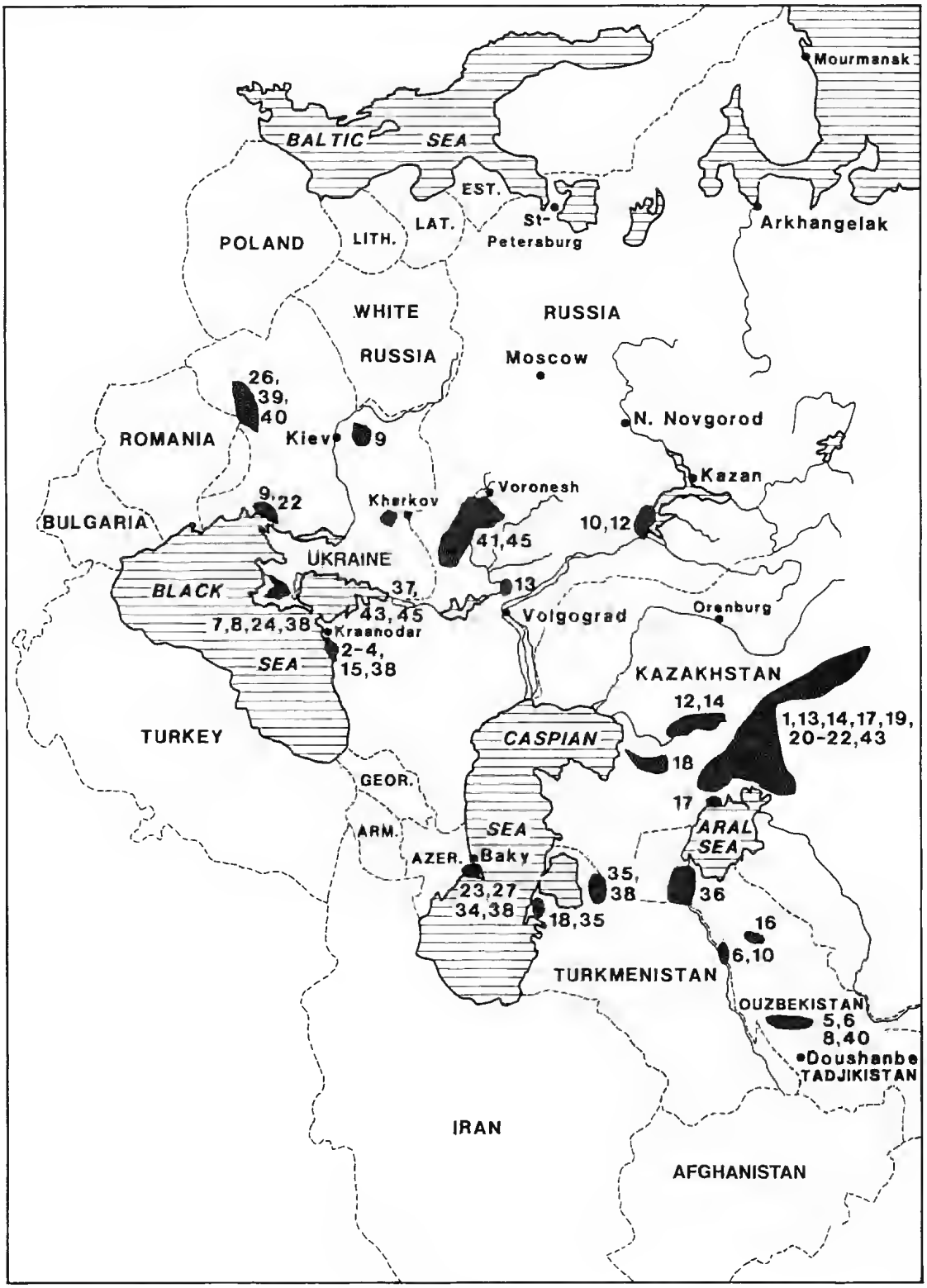

FIG. 6. — General map of eastern Peri-Tethys domain showing the investigated regions listed on Table 2. Main areas of investigation are marked with grey zones. The numbers refer to those given on Table 2. Detail maps are provided from west to east on Figs 7-22.

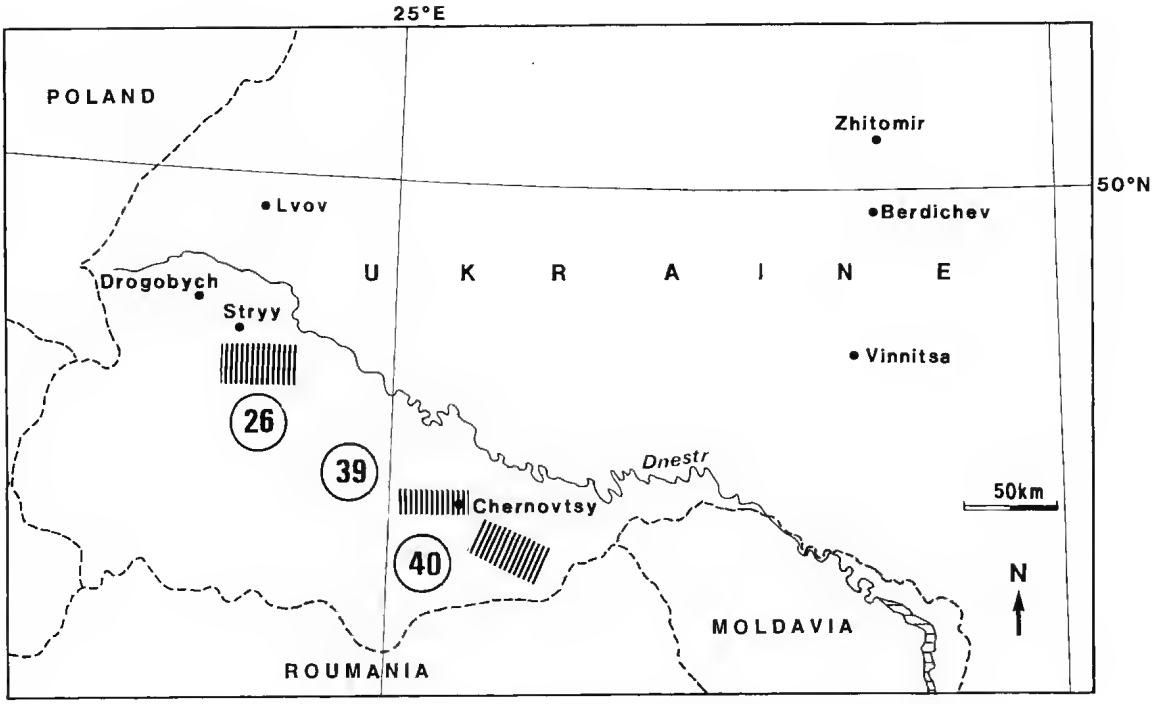

FIG. 7. — Location map of sites used in previously published investigations of Ukraine, south of Lvov (25°E, 50°N).

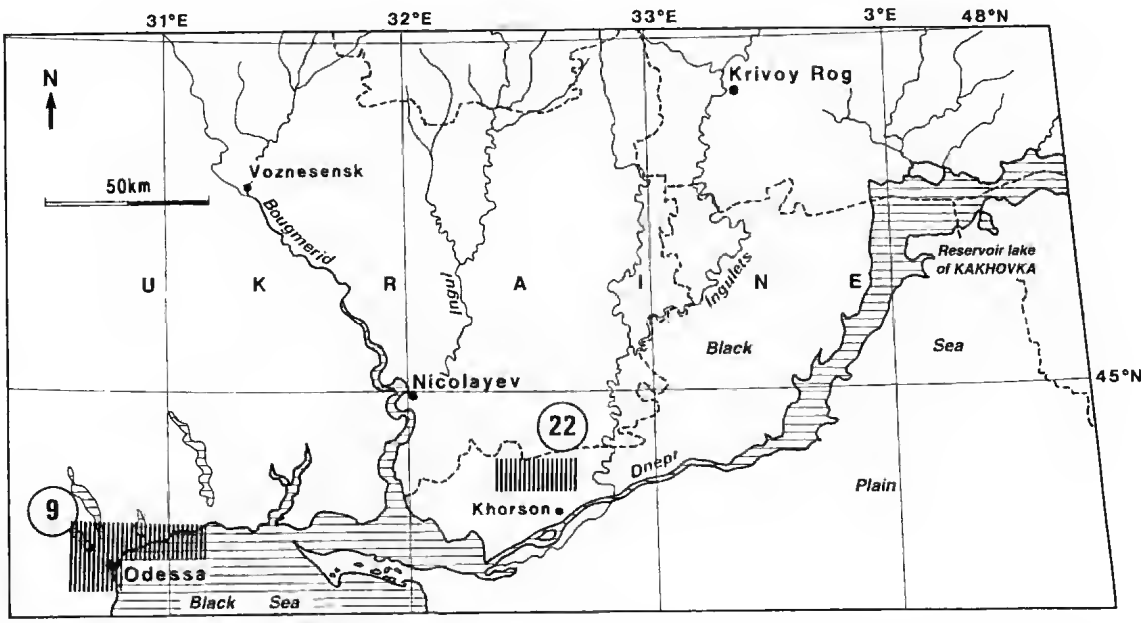

FIG. 8. — Location map of sites used in previously published investigations of Ukraine, northern Black Sea region, near Odessa (31°-34°E, 45°N) .

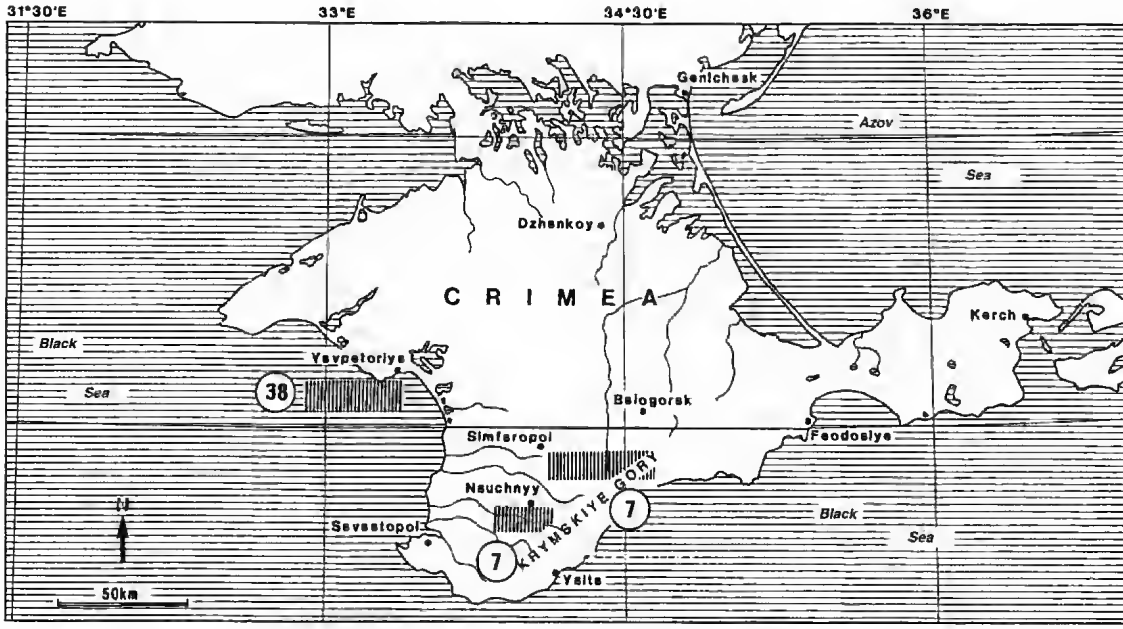

FIG. 9. — Location map of sites used in previously published investigations of the northern Black Sea region Crimea (31°-36°E).

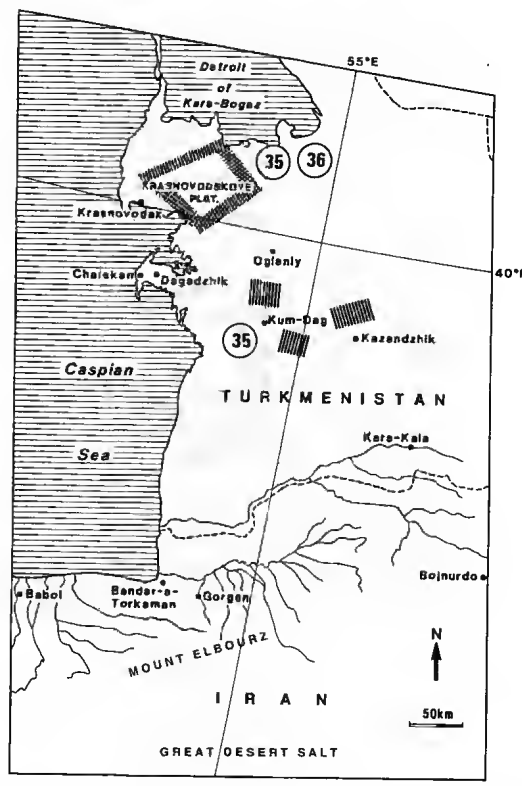

FIG. 10. — Location map of sites used in previously published investigations of the east Caspian Sea, Krasnovodsk area (55°E).

FIG. 11. — Location map of sites used in previously published investigations of Ukraine (31°-32°E, 51°N) in the NE Kiev area.

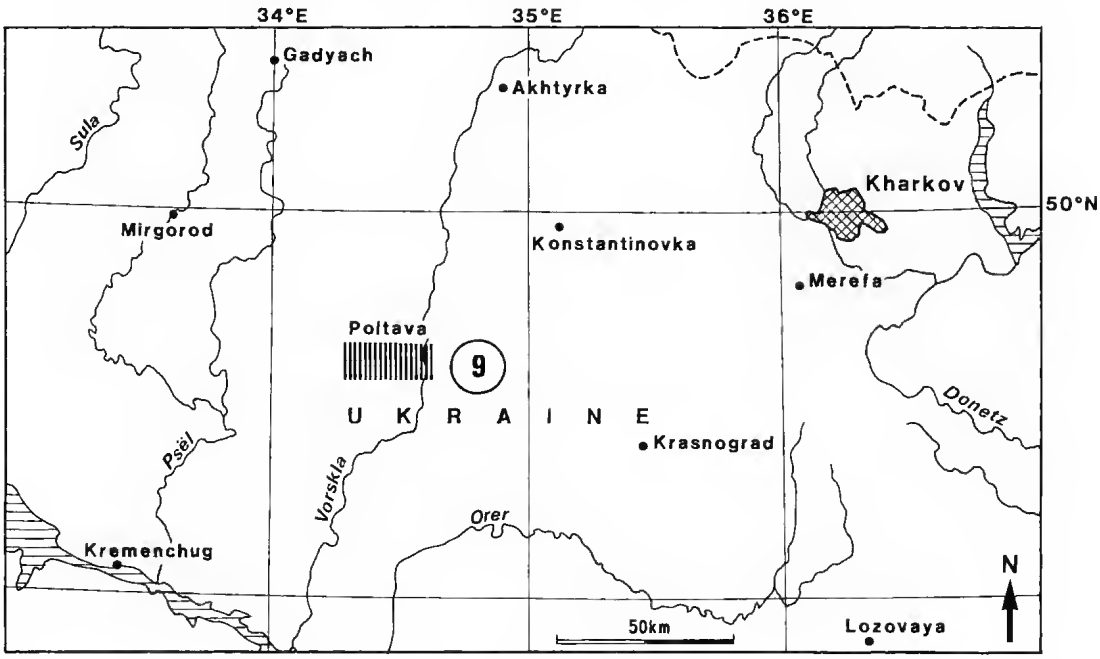

FIG. 12. — Location map of sites used in previously published investigations of the northern Black Sea region in the Kharkov area (33°-37°E, 50°N).

Fig. 13. — Location map of sites used in previously published investigations of the northern Black Sea region in the Lougansk-Stakhanov area (37°-39°E, 48°-49°N).

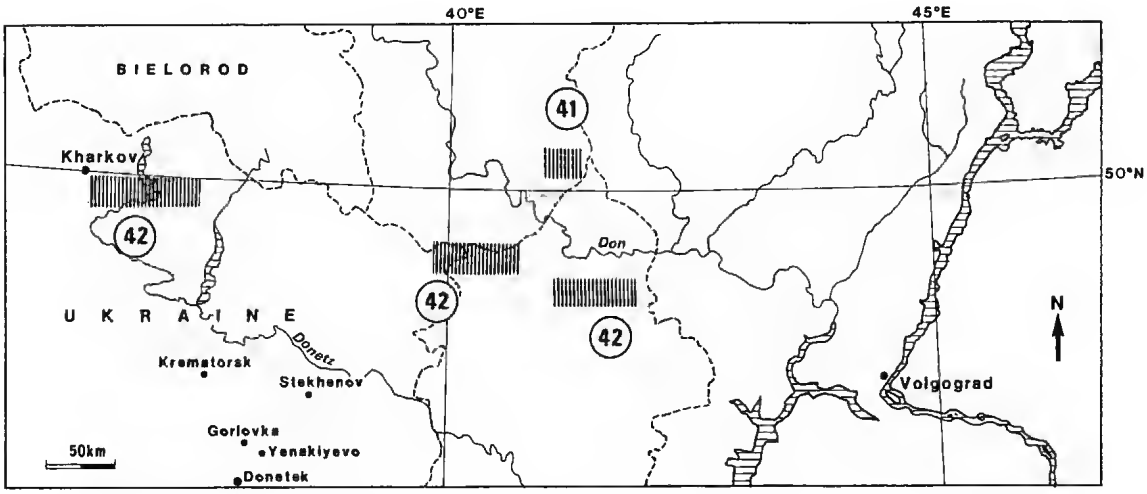

Fig. 14. — Location map of sites used in previously published investigations of eastern Ukraina and south-western Russian platform, Kharkov-Volgograd area (40°-45°E, 50°N).

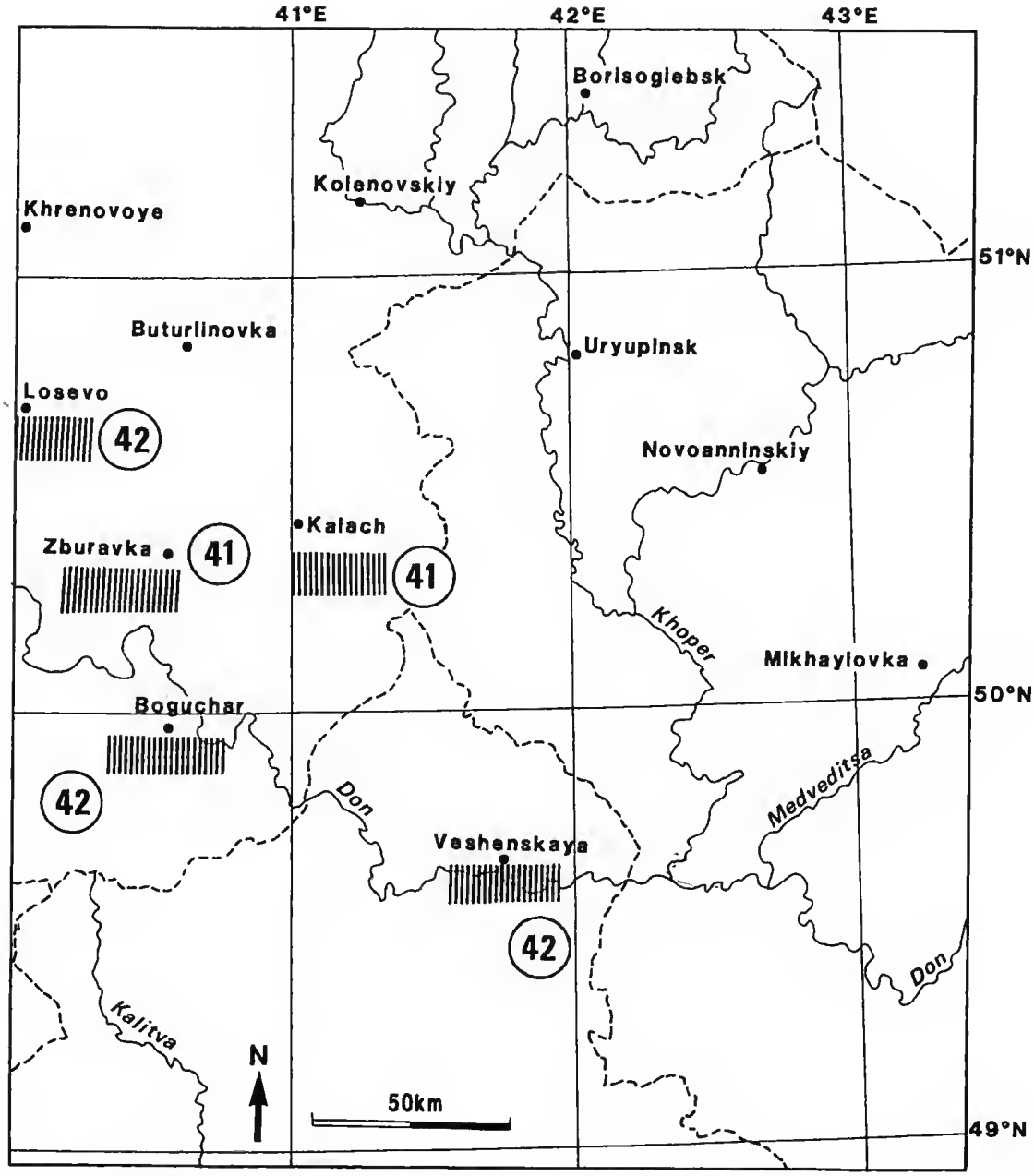

FIG. 15. — Location map of sites used in previously published investigations of eastern Ukraine and south-western Russian platform, Voronesh area (40°-43°E, 49°-51°N).

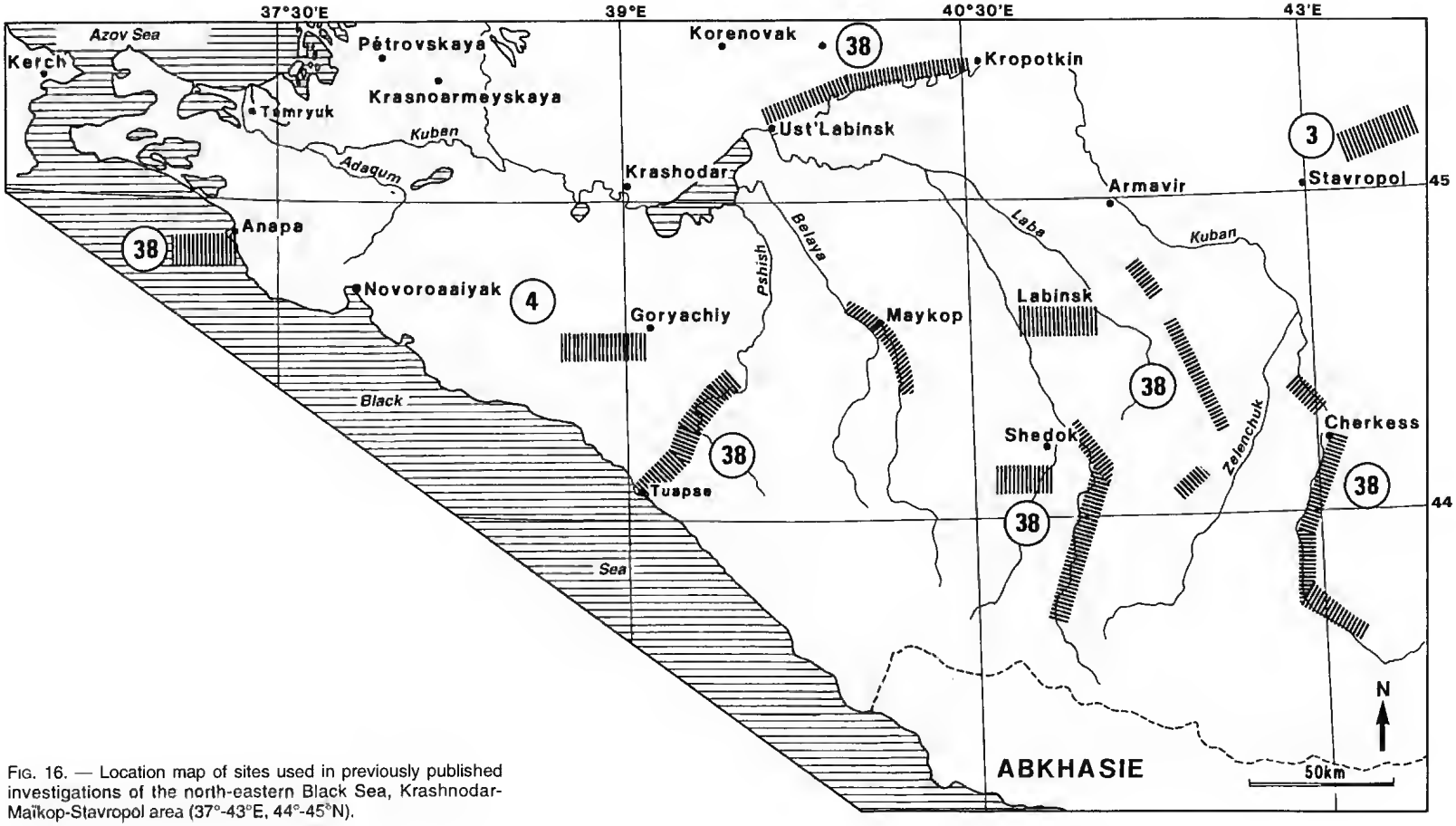

FIG. 16. — Location map of sites used in previously published investigations of the north-eastern Black Sea, Krashnodar-Maïkop-Stavropol area (37°-43°E, 44°-45°N).

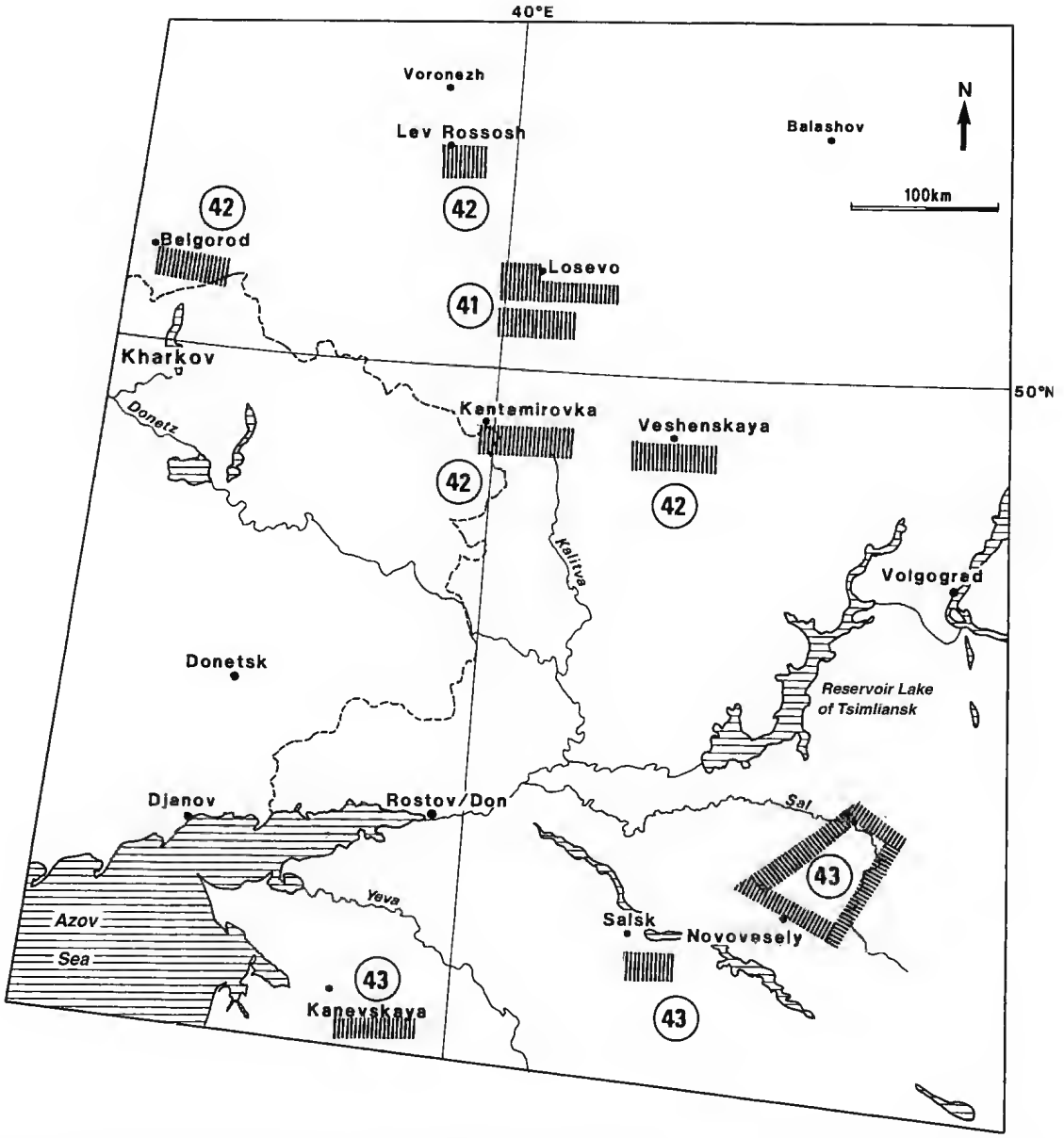

FIG. 17. — Location map of sites used in previously published investigations of the eastern Black Sea, and eastern Ukraina-south-western Russia: Kharkov, Rostov-on-Don and Volgograd regions (40°-45°E, 50°N).

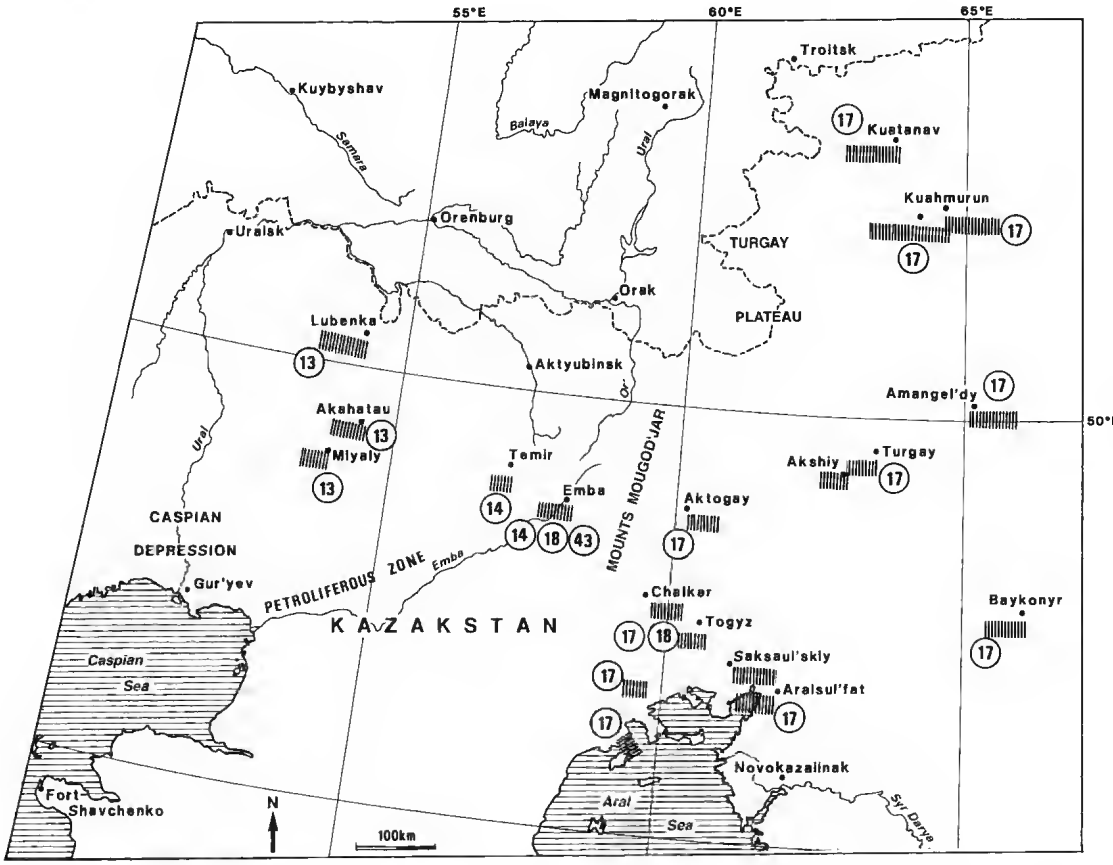

FIG. 18. — Location map of investigations published on northern Kazakhstan-north of Caspian Sea: Kuybishev, Orenbourg and Baïkonur areas.

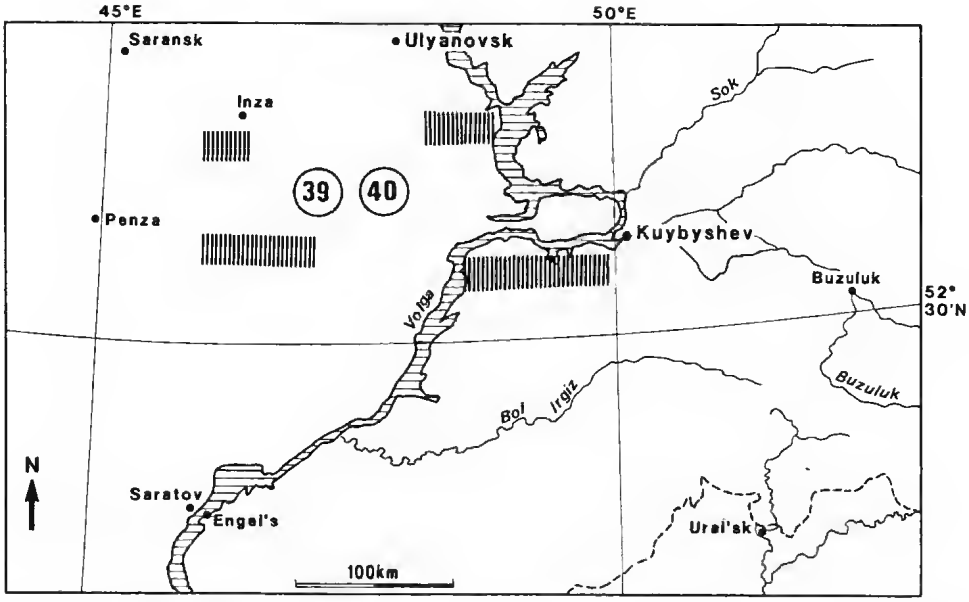

FIG. 19. — Location map of sites used in previously published investigations of the middle Volga between Saratov and Kuybishev (40°-50°E, 52°N).

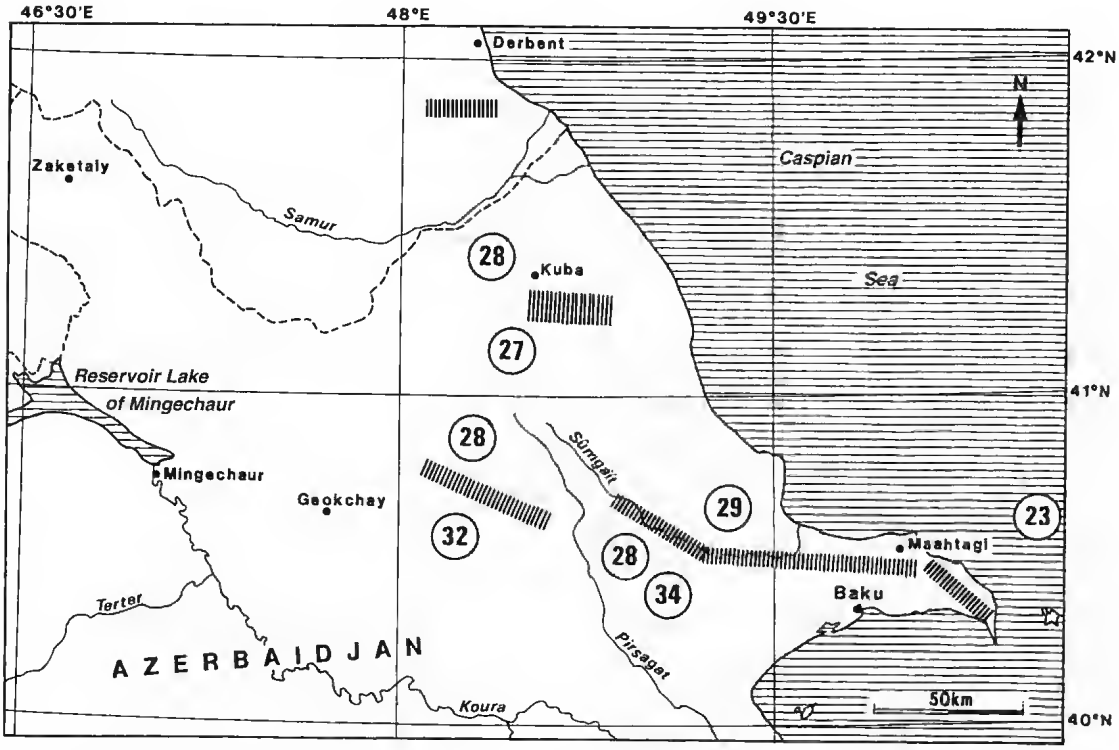

FIG. 20. — Location map of sites used in previously published investigations of Azerbaidzan, Baku area (46°-50°E, 40°-42°N).

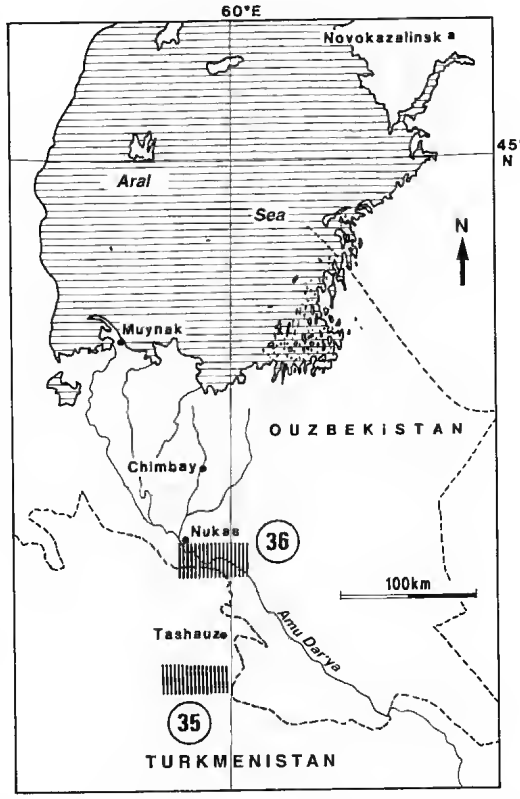

FIG. 21. — Location map of sites used in previously published investigations of the south Aral Sea (NW Ouzbekistan, Nukus area, 60°E, 42°N).

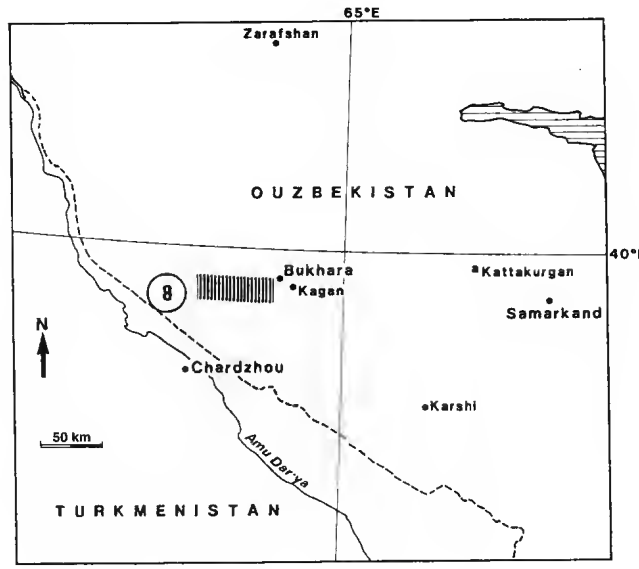

FIG. 22. — Location map of sites used in previously published investigations of on south-east Aral Sea (central Ouzbekistan, west Samarkand area, 65°E).

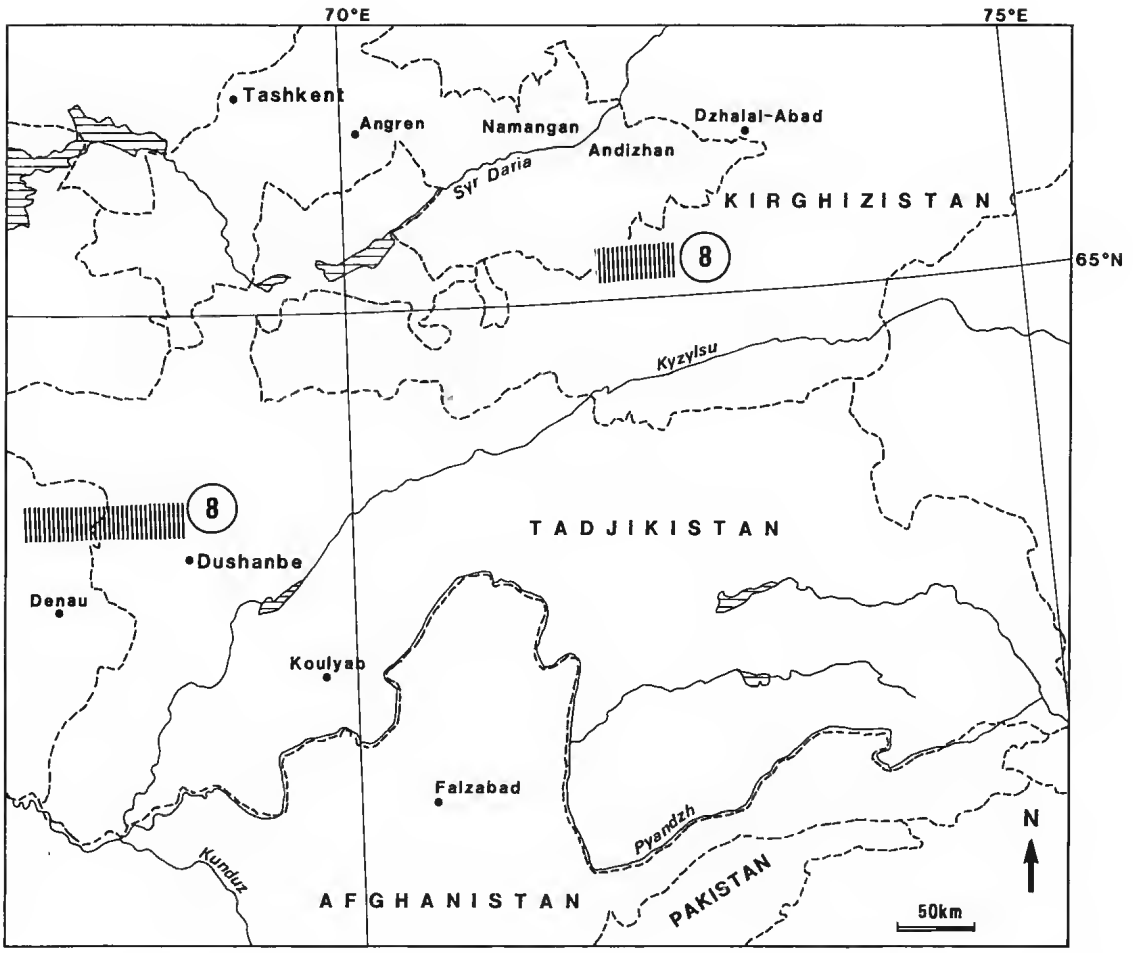

FIG. 23. — Location map of sites used in previously published investigations of Tadjikistan and Dushanbe area (70°-75°E, 65°N) .

Magnetostratigraphy of the Pliocene deposits in Black Sea, Caspian regions and adjacent areas

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Molostovsky E. A. 1997. — Magnetostratigraphy of the Pliocene deposits in Black Sea, Caspian regions and adjacent areas, *in* Crasquin-Soleau S. & De Wever P. (eds), Peri-Tethys: stratigraphic correlations, *Geodiversitas* 19 (2) : 471-495.

ABSTRACT

The results are summarized of paleomagnetic studies of the Pliocene deposits from Kerch Peninsula, western Georgia, Azerbaijan, Turkmenia, North Cis-Caspian and Lower Volga regions. Information from a number of researchers was used alongside with the author's dara obtained earlier and in the course of research within the framework of the Peri-Tethys Programme. Composite paleomagnetic sections from the areas listed were correlated and relared ro A. Cox (Harland *et al.* 1982) magnetochronologic scale and to the paleomagnetic scheme of the Neogene deposits from the Mediterranean region. On rhe basis of rhe paleomagnetic data, the views on chronologic relarionships among some local stratigraphic units were corrected; main development stages of mollusk and osrracode faunas from rhe Black Sea and Caspian regions were analyzed.

KEY WORDS
magnetostratigraphy,
magnetozone,
polarity,
paleomagnetism,
remanent magnetisation,
Para-Tethys,
Pliocene.

RÉSUMÉ

Les résulrars proviennenr d'études paléomagnétiques dans les dépôts pliocènes de la Péninsule de Kerch, de Géorgie occidentale, d'Azerbaidjan, de Turkménie, du nord de la Cis-Caspienne et de la région du cours inférieur de la Volga. Les informations provenant d'autres chercheurs sont utilisées, ainsi que des données de l'auteur au sein er anrérieures au Programme Péri-Téthys. Les coupes paléomagnétiques composites provenant des régions citées sont corrélées avec l'échelle magnétochronologique (Harland *et al.* 1982) du Néogène de Méditerranée. Sur la base des données paléomagnétiques, des corrélations chronologiques enrre différentes unités locales sont revues. Les principaux stades de développemenr des faunes d'ostracodes et de mollusques de la mer Noire et des régions de la Caspienne sont analysés.

MOTS CLÉS
magnétostratigraphie,
magnétozone,
polarité,
paléomagnétisme,
magnétisation rémanente,
Para-Téthys,
Pliocène.

INTRODUCTION

The long process disintegration of the Tethys was finished at the end of the Early Pliocene with the isolation of the Pontic and Caspian basins, after which their interconnections were but short and incidental. The independent development of the post-Tethyan water bodies has affected the composition of their faunal communities. Faunal endemism makes it difficult to divide and correlate the Plio-Pleistocene Formations in the Black Sea and Caspian regions. Some local units still lack any commonly accepted schemes of detailed division, many boundaries remain rather unclear, correlations among the local units and with the Neogene beds of the Mediterranean are ambiguous.

The paleomagnetic studies that have been performed in the last forty years, have played an important part in solving the problems of the Pliocene stratigraphy of the eastern Para-Tethys. During this period some dozens of natural sections and wells in Turkmenia, Georgia, Azerbaijan and the north-western Cis-Pontic region were investigated, which has resulted in a vast paleomagnetic data array systematized on the basis of A. Cox magnetochronologic scale (Harland *et al.* 1982). The most significant results of magnetostratigraphic research are analyzed in the present paper.

The paleomagnetic research in Azerbaijan and western Turkmenia was carried out by Khramov (1963), Trubikhin (1977), Ismail-Zade (1967) and Pevzner (1973). Their data was used as the basis for the corresponding parts of the present paper. The materials from other regions were collected and analyzed under direct supervision of the author. The sections from Kerch Peninsula and the North Cis-Caspian were studied within the framework of the Peri-Tethys Programme. While summarizing the results on Kerch and West Georgia, the author's information was supplemented by the data from Molostovsky *et al.* (1982, 1983).

Of principal importance for the Pliocene magnetostratigraphy in the eastern Para-Tethys, was A. Cox magnetochronologic scale, used as the basis for elaboration of stratigraphic relations among local units and their position in the general magnetic polarity scale. The magnetostratigraphy of the Pliocene beds from the Black Sea and Caspian regions, was essentially formed on the basis of A. Cox scale, and this is reflected in the present paper.

The information on laboratory methods and for the nature of natural remanent magnetism (NRM) can be found elsewhere and are not considered here give references, the only exception being the author's materials on Georgia, Kerch Peninsula, North Cis-Caspian and Volga regions, where the works were conducted under his direct guidance (Fig. 1).

RESEARCH METHODS

The principal attention was focused on reference sections paleontologically well characterized. They were investigated in cooperation with geologists and paleontologists. Paleomagnetic sampling was made in parallel with fossil collection which provided reliable stratigraphic reference for magnetozones. The "top-bottom" oriented cores were selected from wells at the time of their extraction from the corers.

The sample remanent magnetization was measured with ION-1 and JR spinner magnetometers. Temperature magnetic cleaning was performed in the furnaces with m-metal screens by means of successive heating up to 400-500 °C. Heating regimes were selected experimentally with leading collections of 20-25 samples. No less than two cubes were selected for thermal cleaning from every level; their position in furnace was anti the parallel. Some samples were subjected to control cleaning with alternating field within a Helmholtz coil system in the range of $16\text{-}40 \times 10^{-3}$ A/m.

To diagnose the compositions of magnetic phases, optical and X-ray structural analyses alongside with differential thermomagnetic analyses (DTMA) were used, normal magnetization curves, Jr and Jrs, were measured, destroying fields of saturation magnetizations (H'cs) were determined.

The characteristics listed above allow to judge upon Curie points (Cp), the spectra of blocking temperatures, sizes and oxidation degrees of magnetic particles and, as the result, upon chemi-

cal compositions of the principal magnetic phases. To determine the natural remanent magnetization components and their directions, the samples were heated successively (in fifty increments) up to 400-600 °C. The process of demagnetization was analyzed by means of Zijderveld diagrams.

It is practically impossible to perform the labour-consuming experiments on each sample, if large collections are being studied, with hundreds of sampling levels from many sections represented. Therefore, to study the NRM component contents and to make mineralogic analyses, 15-25 samples with various lithologic compositions were selected from normal and reverse magnetization zones in each section, which made about 20-25% of the overall amounts of the collections. The results thus obtained were extrapolated, each magnetozone being provided with magnetic-mineralogic determinations from at least 5-10 stratigraphic levels, and narrow events from at least 2-3 ones.

Three types of NRM-carriers have been revealed:

1. Detrital magnetite constitutes the principal magnetic phase in the Pliocene deposits of western Georgia and partially of the Kerch Peninsula and the Low Volga region. It forms angular and subrounded grains of 0.01-0.1 mm size. On

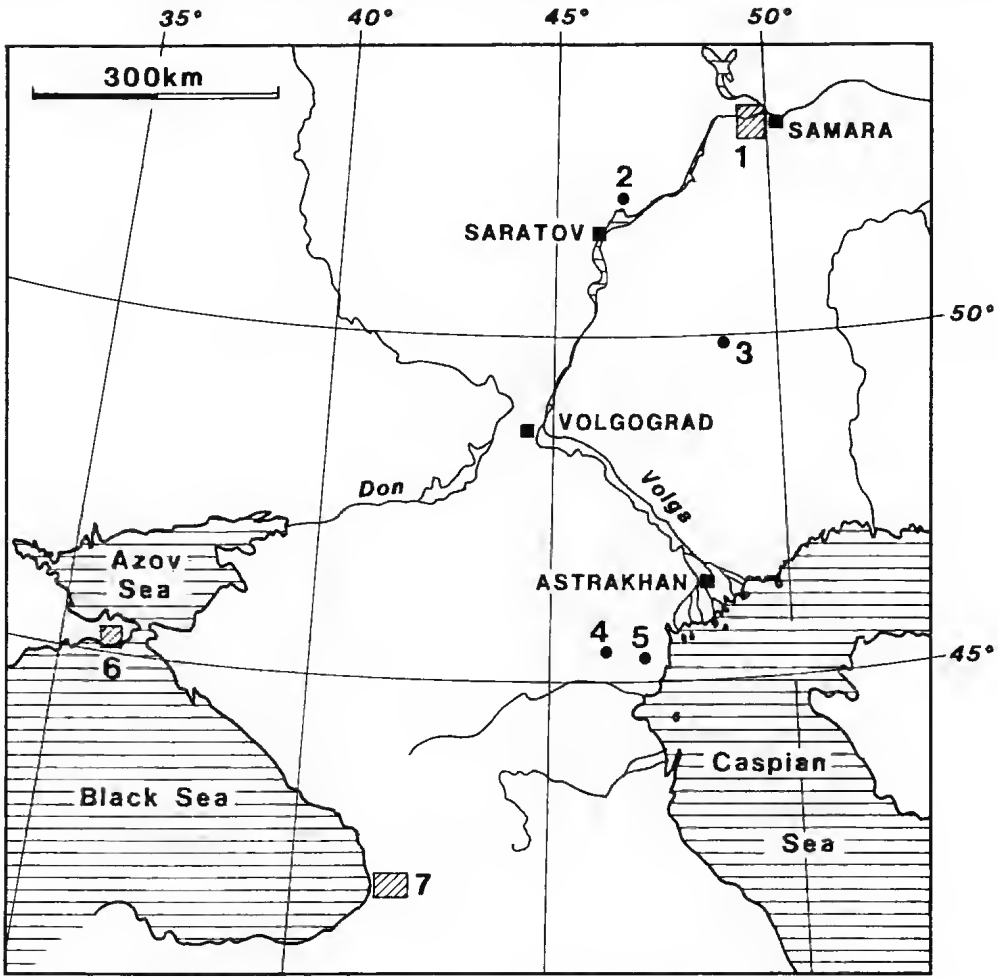


FIG. 1. — Location map showing studied sections. Sections: **1**, well 1, 5, 13, 14, 15, 18, 19 (Samara Region). **2**, well 3 (Saratov-Volga region). **3**, well 20 (Saratov-Volga region). **4**, well 13 (Kalmykia). **5**, well 48 (Kalmykia). **6**, Kerch Peninsula. **7**, West Georgia.

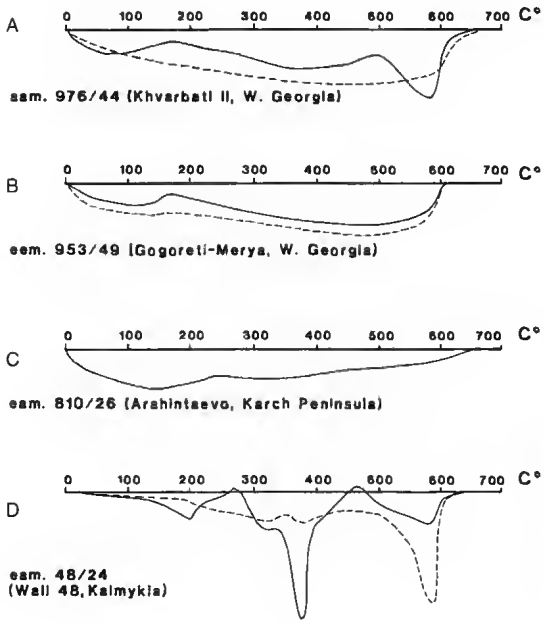


FIG. 2. — Differential curves of thermal demagnetization of Pliocene samples: **A**, **B**, magnetite samples; **C**, hydroxyde samples; **D**, authigenic greigite and pyrrhotite samples. Continuous line, first heating; pecked line, second heating.

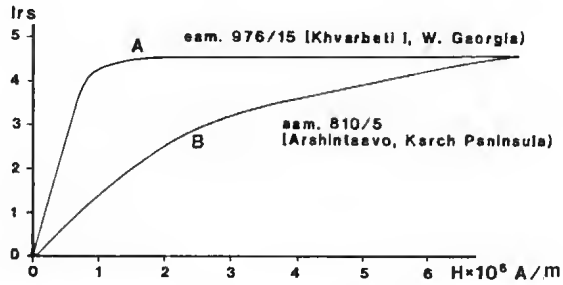


FIG. 3. — Curves of normal magnetization. **A**, magnetite samples; **B**, hematite samples.

DMTA curves it is marked with sharp Js dip at 570-580 °C. It does not display anyclear effect in Cp in finely dispersed fractions and is characterized by a wide range of blocking temperatutes with the loss of Js et around 570 °C (Fig. 2A, B).

2. Iron ores from the Kerch region and some red clays from the Volga region possess remanent magnetization due to finely dispersed iron oxides. DMTA curves of these rocks show Js dips in the T range of 150-250 °C and at hematite Cp (Fig. 2C). Normal magnetization curves for the rocks of the first and second groups are presented in figure 3A.

3. Within a substantial portion of the Pliocene clays from the North Cis-Caspian and Volga regions, the chief Jn carriers are represenred by authigenic iron sulfides of the FeSx type with $1.1 \leq x \leq 1.6$.

Authigenic magnetic sulfides are morphologically diverse and occur as rounded, tubular or irregular aggregates that concentrate in accumulations close to vegerable detritus, frequently in association with pyrite. Optical and X-ray analyses have proved them to be melnikovite (greigite) from the Cp of 380 and 420 °C (Fig. 2D). Magnetothermal analyses occasionally reveal hexagonal pyrrhotine among the sulfides, producing characteristic peaks in the 260-300 °C range (transition to monoclinal modification).

A series of paleomagnetic-sample thermal cleanings within the temperature range up to 500 °C was performed for the analyses of remanent magnetization component vectors. The results were used to construct Zijderveld diagrams.

Two components are characteristic of detrital NRM-carriers in the sections from western Georgia: the primary component, synchronous with sediment generation, and the secondary one, viscous, formed during subsequent geologic epochs. The metachronous secondary magnetization is completely cleated away when rock samples are heated up to 100-200 °C (Fig. 4A-D), leaving behind the true direction of the primary remanent magnetization.

Three NRM-components are characteristic of the Pliocene clays from the northern Cis-Caspian and Volga regions (Fig. 4E-H). The viscous secondary magnetization is, as a rule, cleared away when a rock sample is heated up to 100 °C. The primary magnetization, synchronous with sediment deposition is associated with authigenic sulfides and does not change its direction markedly when heated up to 200-300 °C. When a sample is heated above 300-400 °C, metachronous stable magnetization is displayed, associated with the secondary minerals magnetite and hematite which are formed within rocks as the result of ptimary sulfide oxidation. These components are most clearly seen in the samples from R-zones (Fig. 4E-H).

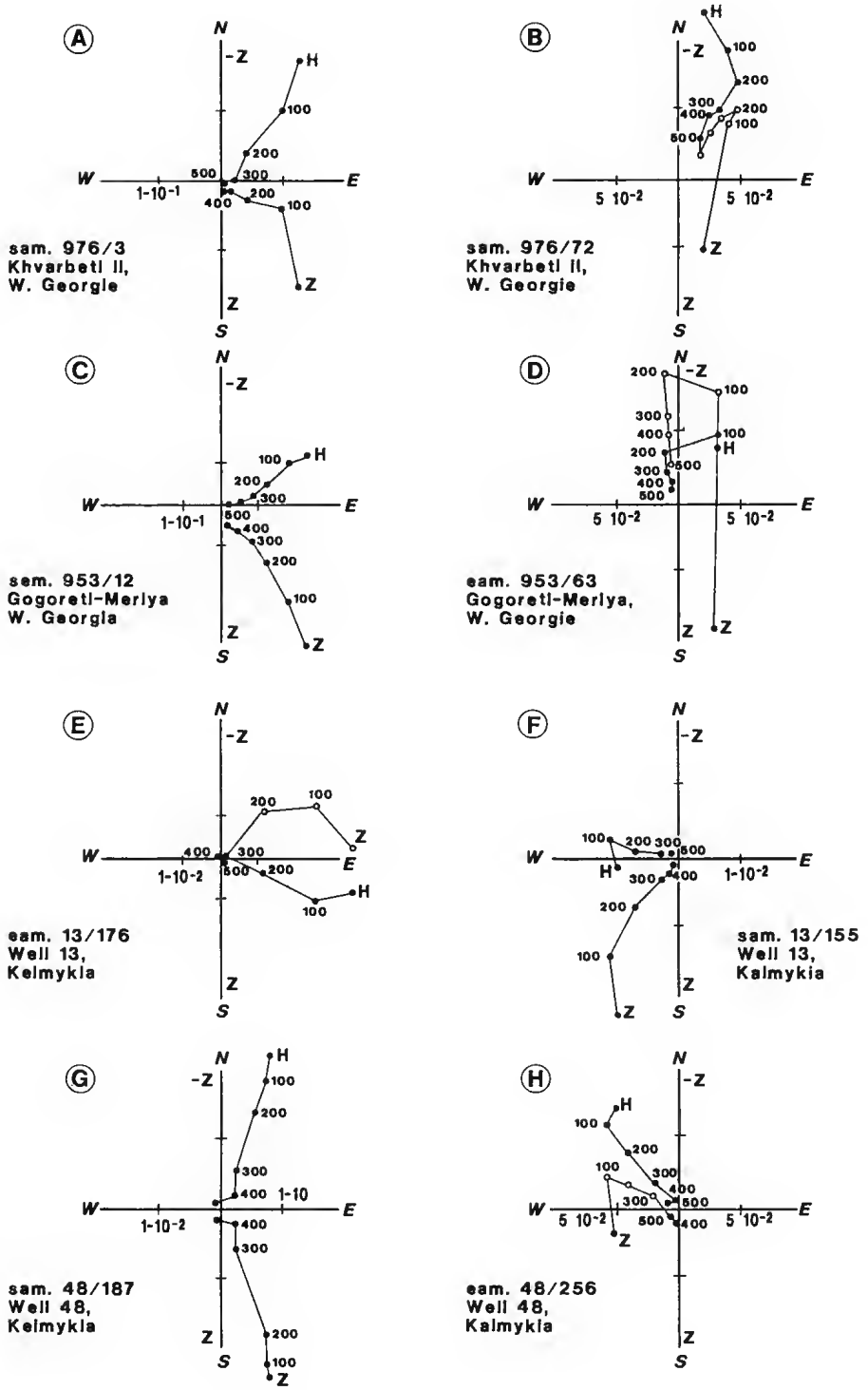


FIG. 4. — Zijderveld diagrams of thermal demagnetization of the Pliocene samples. West Georgia (**A-B**) and North Cis-Caspian region (**E-H**).

A similar process is observed in laboratories when collections are stored for long periods. Reversely magnetized samples in such cases frequently acquire stable normal magnetization. The change of magnetization polarity resulting from the influence of the secondary magnetic phases after the destruction of primary sulfides is clearly demonstrated in figure 4E, H.

The basic problem of any paleomagnetic study (providing evidence for NMR priority and geophysical nature of magnetozones) can't be ultimately solved through laboratory experiments. Some indirect tests prove to be helpful, which to a certain degree help to demonstrate the validity of conclusions on NRM primary nature.

To achieve this, beside the conventional tests (Khramov & Sholpo 1967; Khramov 1982), a number of additional features were used, applicable to the sequences with various compositions and dislocation degrees:

1. The closeness of Jn vector distributions was compared between rocks from various lithologic groups. In case of detrital magnetization, closeness of Jn vectors in psammite-class rocks should generally be less then in aleuro-pelites.

2. Jn polarity independence of lithology, facies and magnetic phase compositions was estimated. Association of various-type rocks to the zones of the same magnetization, and on the contrary, alternation of diverse-polarity zones within the monofacies sections, were regarded as indicative of the primary nature of NRM.

3. Geophysical nature of magnetozones is indicated by their lateral stability, consistency within certain stratogenetic series: marine, deltaic, alluvial and other facies. Testing of outer convergence with corresponding paleontologic and radiometric controls, is probably the strongest argument for confirming the primary character of NRM.

Some results of magnetostratigraphic research of the Pliocene deposite from individual regions are presented below.

REGIONAL MAGNETOSTRATIGRAPHIC SCHEMES

Western Georgia (Guria)

The author in cooperation with paleontologists Kitovani and Imnadze has examined forteen sections. The whole of the western Georgia's Pliocene is presented in clear sequence with multiple overlappings: from the base of the Pontian through the top of the Gurian Chauda. This thick complex of terrigenous sediments is rather monotonous lithologically. Blue and dark-grey massive clays and aleurites prevail over subordinate interlayers of polymictic sandstones. Stratigraphic division of the sequence is performed according to ostracode and mollusk faunas. In the present paper it is subdivided from the bottom to the top of the section according to the schemes by Kitovani and Imnadze (Kitovany 1976).

The Pontian stage (180-210 m)
Characterised by a specific mollusk fauna: *Congeria digitifera* Andrussow, *Paradacna abichi* R. Hoernes, *Monodacna pseudocafilus* Barbot de Marny, etc.

The Kimmerian regional stage
According to the mollusk fauna, it is subdivided into a lower (Azov) horizon (8-12 m) with *Limnocardium* Andrussow *et al.* The middle and the upper horizons are not divided (30-70 m) but established from the appearance of *Dreissena polymorpha* Pallas, *D. angusta* (Roussean), *Didacna crassatellata* Deshayes, etc.

The Kuyalnikian regional stage
Represented by layers with mixed Kimmerian-Kuyalnikian malacofauna and typically Kuyalnikian bedding with *Didacna medea* Daviaschvili, *Submodacna pleonexia* Daviaschvili, *Monodacna postdonacoides* Daviaschvili, etc. The overall thickness of the Kuyalnikian thus defined constitutes 15-20 m.

The Gurian horizon (80-90 m)
Begins with beds containing *Dreissena* ex gr. *rostriformis* Deshayes. The main part of the section is characterized by *Digressodacna minor* Kitovani, *D. digressa* (Livental), *D. longipes* Kitovani, etc.

The Nagobilevsky (Chauda) horizon (50-90 m)
Is at the top of the Pliocene section in western Georgia and may be lowermost Pleistocene in

part. The Gurian Chauda is characterized by rich and diverse malacofauna: *Digressodacna gracilior* Daviaschvili, *Tshaudanissa* Kitovani, *T. guriana* Livental, *Didacna pseudocrassa tipica* Livental, etc.

The Pleistocene

A 90 m thick sequence of sands with subordinate clay interlayers exposed in two sections studied containing ostracodes that are characteristic of ancient euxinic beds: *Caspiola gracilis bacuana* (Lubimova), *C. acronasuta* (Livental), *Leptocythere bicornis* Aslanova, etc.

Comparison

The Pliocene deposits from western Georgia are characterized by high magnetism with regular distribution of Jn and æ values over the stratigraphic section. The lower part of the Pontian is relatively low magnetic (Jn = 3-17 × 10^{-3} A/m, æ = 10-50 × 10^{-5} SI units). In the Upper Pontian and Kimmerian beds, these parameters are 20-40 × 10^{-3} A/m, æ = 100-280 × 10^{-5} SI units. The Upper Pliocene part of the section, rock magnetism reaches the maximum values: Jn = 40-150 × 10^{-3} A/m, æ = 300-1400 × 10^{-5} SI units.

Optical methods and DTMA have revealed detrital magnetite grains of 0.1-0.005 mm size in all lithologic rock varieties. It may be present as even smaller, dust-like particles. No other probable NRM-carriers were detected in rocks.

Detrital origin of the optically diagnosed magnetite is established from angular grain outlines, water-transportation marks in the form of scratches and scores, aggregations with silicate minerals. There is the dependence of magnetic fraction distribution on the rock textural features: accumulation within oblique sandstone interlayers, due to natural rewashing of sediments, increased concentrations in basal layers, accumulations of dust magnetite particles on lamination planes.

The share of metachronous viscous magnetization reaches 60-70% of the sum Jn, but in most samples it is reduced upon heating up to 200 °C. No peculiarities were observed in the behaviour of NRM vectors relative to rock lithologic or facies compositions. Just a wider dispersion in Jn directions is observed in sandstones compared to aleurolites and clays. At the same time, regular distribution of normal and reverse magnetization intervals is observed along the time scale, as well as their recurrence in the sections, reliably referenced according to fauna.

Paleomagnetic zonality peculiarities in the Pliocene and Quaternary deposits from some reference sections are presented in figures 5, 6, paleomagnetic correlation of the sections in figure 7.

Comparisons of the individual columns make it possible to distinguish four magnetozones, complicated with narrow opposite-polarity subzones, within the recent deposits from western Georgia. The first from below Rn zone includes the whole of the Pontian plus the Lower and the Middle Kimmerian. In the uppermost part of the Pontian and in the Lower Kimmerian from Khvarbeti II, Makharadze and Gogoreti-Meriya sections, four n-subzones are traced, each one from 3-6 m thick. The middle Kimmerian deposits are reversely magnetized everywhere. On the whole, the structure of the lower Rn interval, as well as the stratigraphic range occupied, make it possible to refer the interval to the Gilbert Zone in the general magnetochronologic scale.

The lower Kuyalnikian and upper Kimmerian parts of the section, reduced due to ancient erosion, are relatively less well known. The upper Kimmerian in the Khvarbeti II outcrop is composed of normally magnetized beds with the apparent thickness of abour 5 m. The lower Kuyalnikian horizon also reveals normal polarity Jn within outcrops along the Skurdubi and Tsina-Gele rivers and in some other localities where the apparent thicknesses at outcrop constitute 6-8 m (Fig. 7).

Zubakov (1990) established the stratigraphic range of this N-zone within parallel sections with the upper Kimmerian and the lower Kuyalnikian and identified it with Gauss Zone.

Stratigraphically higher, there is a large reverse polarity interval embracing the Nagobilevsky (Chauda), Gurian and the upper half of the Kuyalnikian and unambiguousaly identified with the Matuyama Zone. Four successive N-subzones were recognized and traced along the strike within this zone: from the middle of the Chauda

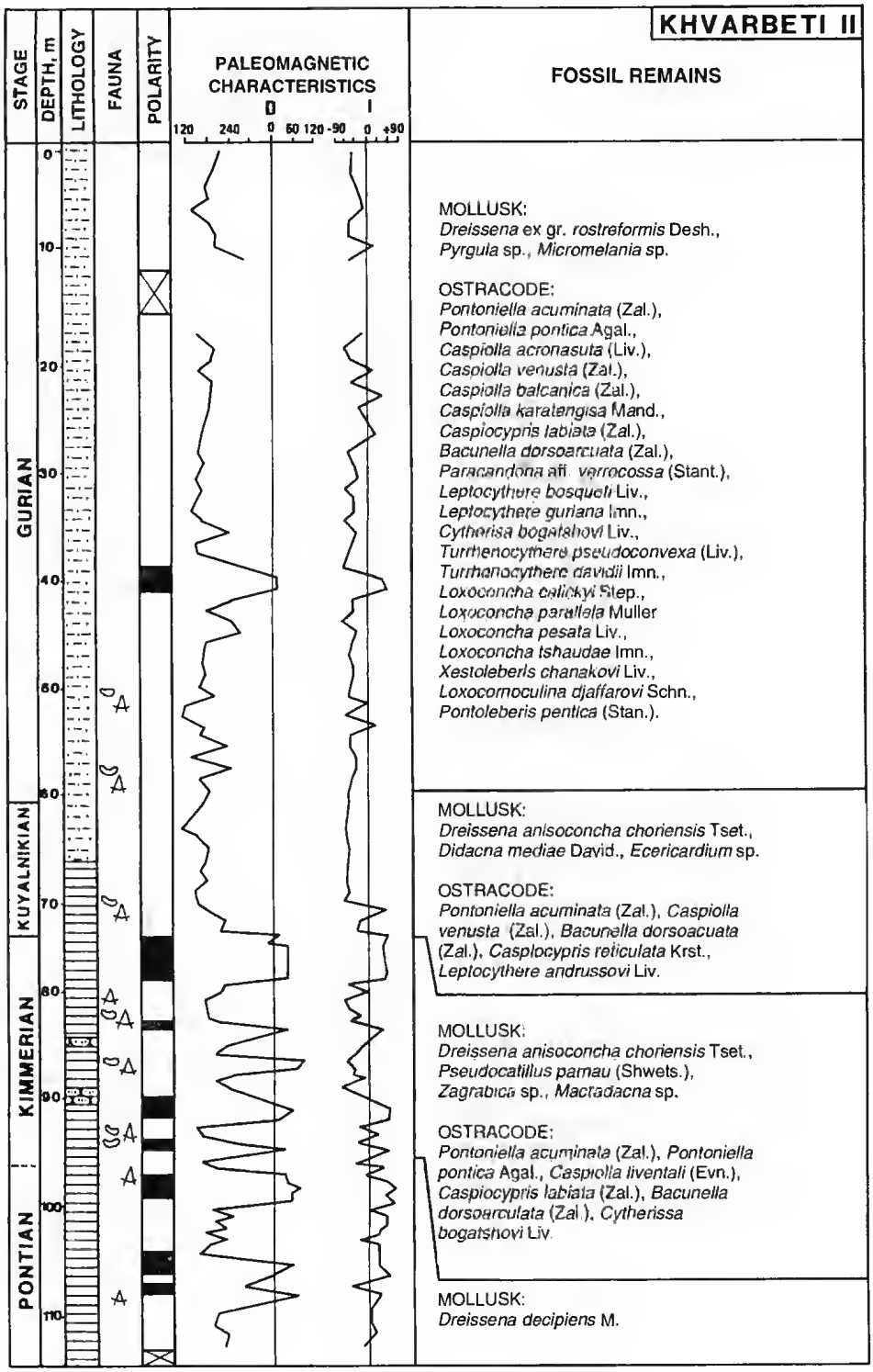


FIG. 5. — Paleomagnetic section of the Pliocene deposits of western Georgia.

in the top of the Gurian, at the Gurian-Kuyalnikian boundary, in the upper part of the Kuyalnikian (Fig. 7).

The first, third and fourth subzones are most logically interpreted as being analogous to the Jaramillo, Olduvay and Reunion episodes. The second subzone, from the uppermost Gurian with the Kwemo-Natanebi episode, has also been recognized by Zubakov & Kochegura (1976) at the same stratigraphic level in western Georgia. The age of the later according to thermoluminescent analysis is 1,1-1.2 Ma; chronologically similar N-subzones have been found within basaltic covers of Madeira Island and in California (Mancinen *et al.* 1978).

The upper zone of normal magnetization corresponds to the ancient euxinic beds and from its stratigraphic position may be identified with the middle part of the Brunhes Zone. It is complicated with a reverse-sign subzone, most possibly analogous to the Lower Khazarian (Dnieper) episode with the absolute thermoluminescent dating of 0.35 Ma (Zubakov 1990).

LEGEND FOR FIGS 5-8, 11

Jn	Natural remanent magnetization
æ	Magnetic susceptibility
N, n	Normal polarity Jn
R, r	Reverse polarity Jn

Intervals of normal polarity (N)

Intervals of reverse polarity (R)

Absence of deposits or absence of polarity data

Clay

Aleurolite

Sand

Sandstone

Limestone

Iron ore

Pebble and gravel

Gap

Mollusk

Ostracode

THE NORTH-WESTERN CIS-PONTIC REGION

The recent deposits from Taman, Kerch Peninsula and northern Cis-Azov region were paleomagnetically studied by Tretyak & Volok (1976), Semenenko & Pevzner (1979), Molostovsky *et al.* (1984) and Zubakov (1990). Individual portions of the section are presented here from natural outcrops. A continuous succession was studied by Semenenko & Pevzner (1979) from the well cores. Up to now, practically the whole of the Pliocene sequence from the base of the Pontian stage through the overlaying Pleistocene loams has been characterized paleomagnetically (Eberzin 1940).

The Pontian stage

With the characteristic malacofauna of *Paradacna, Valenciennius* and *Congeria*, it is represented by 20-120 m thick monotonous grey clays.

The Kimmerian stage

The Kimmerian stage, as distinct from the Pontian, is lithologically well differentiated. Its lower (Azov) horizon, when present, is distinguished by its variable composition. This consists of clays, iron sands and poor iron ores in Taman; in the Chegercha syncline in Kerch Peninsula, it is recognised within a clayey monofacial section by the substitution of the Pontian *Paradacna abichi* R. Hoernes by the Kimmerian *Paradacna deformis, Dreissena rostriformis* Deshayes, etc.

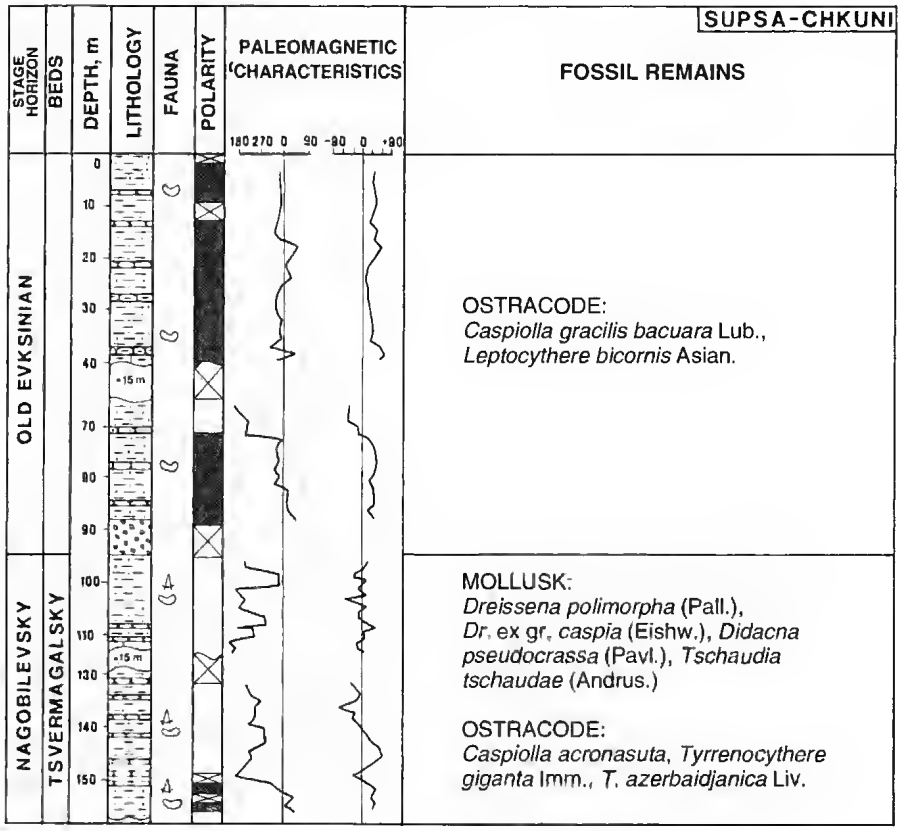
The middle (Kamyshburun) horizon is built of massive iron ores containing abundant *Dreissena, Paradacna, Monodacna*, etc.

The top (Pantikapei) horizon is composed of grey and olive clays with thin interlayers of poor iron ores.

The thickness of the Kimmerian does not exceed 20 m within the zones of shallow-water sedimentation and increases up to 220 m in the axial parts of the synclinal basins.

The Kuyalnikian stage

The Kuyalnikian stage in the eastern part of the Kerch Peninsula lies unconformably upon



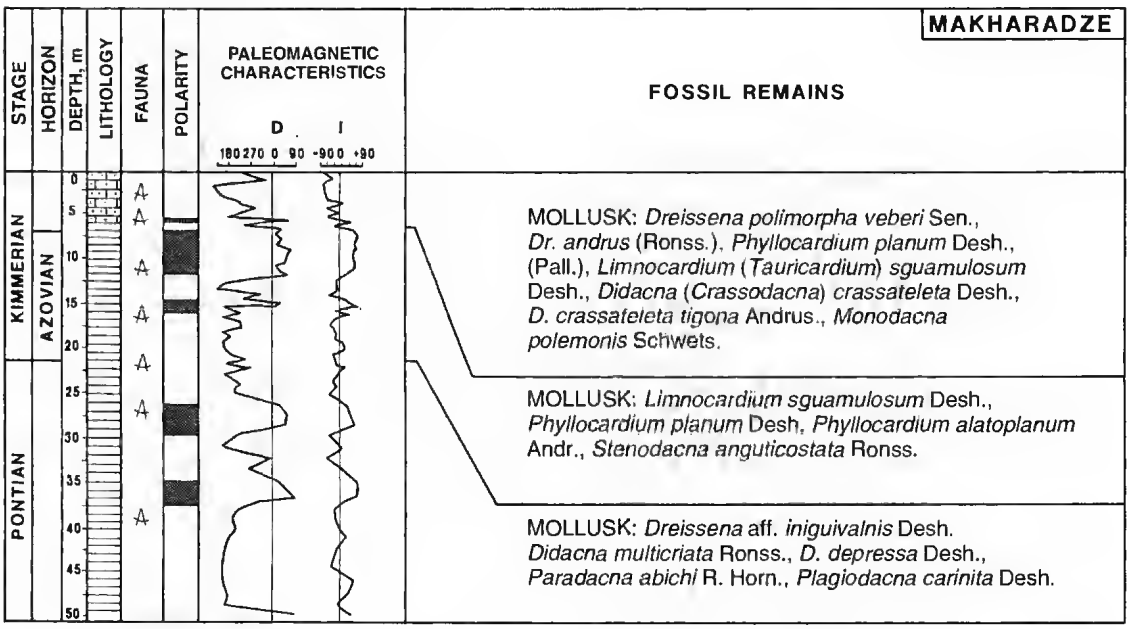


FIG. 6. — Paleomagnetic section of the Pliocene and lower Pleistocene deposits of western Georgia. Legend: see figure 5.

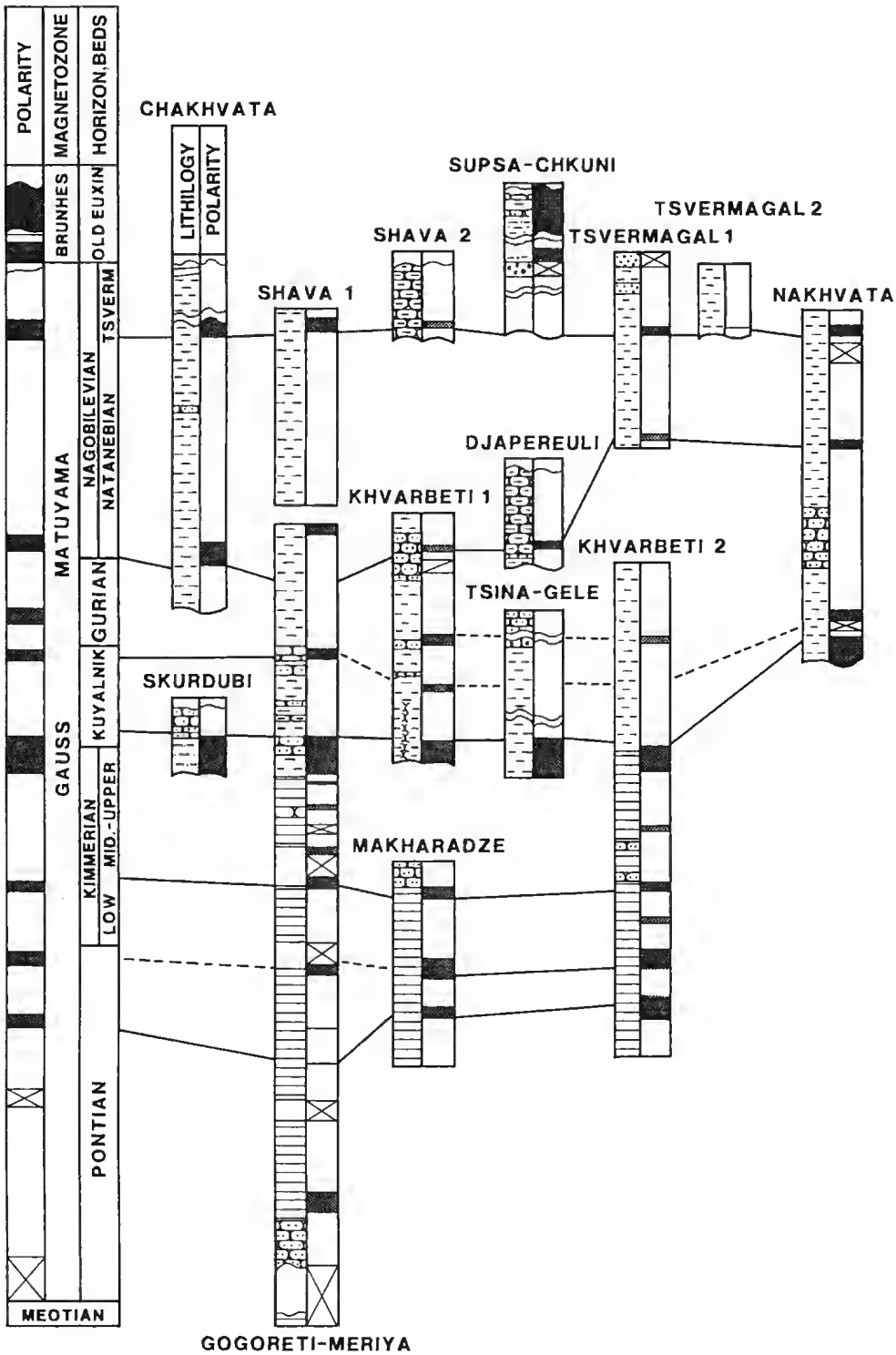


FIG. 7. — Paleomagnetic section and correlation of the Pliocene deposits of western Georgia. Legend: see Fig. 5.

various Kimmerian horizons. It is represented by a 12-16 m thick unit of bluish-grey clays and sands. The thickness of the Kuyalnikian beds is as high as 80 m in the Chegercha synclinal fold. The *Dreissena* (and *Lymnocardium*) containing bearing layers belong to the lower Kuyalnikian here, and the overlying Taman layers with *Avimactra subcaspia* Andrussow and *Cardium dombra* Andrussow to the upper Kuyalnikian (Nevesskaya *et al.* 1986).

Continental analogues of the marine Kuyalnikian are common in the Cis-Azov region, with the well-studied sequences of small mammal from the lower (Kuyalnikian) and the upper (Odessian) parts.

The Kuyalnikian sequence is succeeded by the Tyup-Djankoi beds; the Pliocene section is crowned with a clay member attributed to the "Gurian" layers. The Tamanian beds may serve as a good correlation reference; they overlie older deposits and are recognized by the Actchagylian-type mollusks.

Comparison

The Pliocene deposits from Kerch Peninsula and the adjacent areas are generally low magnetic: Jn = 0.3-0.8 × 10^{-3} A/m, æ = 10-15 × 10^{-5} SI units. In the iron ores Jn reaches 1-2 × 10 × 10^{-3} A/m, æ = 20-55 × 10^{-5} SI units.

The magnetic properties of the bulk of the rocks are determined by fine clastic magnetite. In iron ore layers, NRM is mainly carried by authigenic FeO.OH and Fe_2O_3 developed over siderite and chlorite.

Substantial metachronous magnetization, coinci-

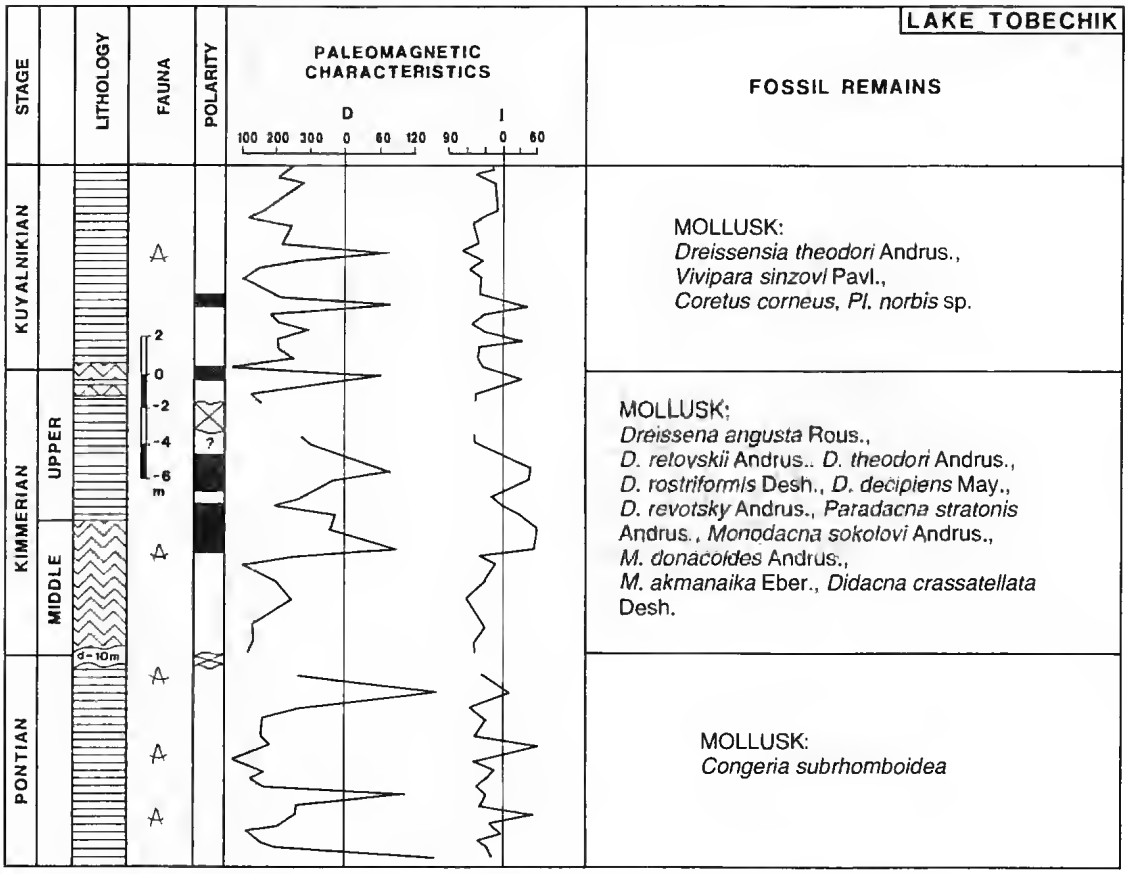


FIG. 8. — Paleomagnetic section of the Pliocene deposits in Kerch Peninsula. Legend: see figure. 5.

ding with the recent field, is present practically in all the rocks. Its main part is destroyed in the 200-300 °C temperature. Jn components allow to judge on the section magnetic zonalities quite confidently. It is necessary to note that the distribution of the normal and reverse magnetisation intervals doesn't depend on lithology, facies or composition of magnetic minerals. It is seen from figure 8, that the layers with detrital magnetite from various parts of the section are characterized by NRM of various polarities. At the same time, within the middle Kimmerian, the ore horizons with chemical remanent magnetization reveal the same Jn polarity as the hosting clays with allothigenic magnetite.

Paleomagnetic columns for the principal sections

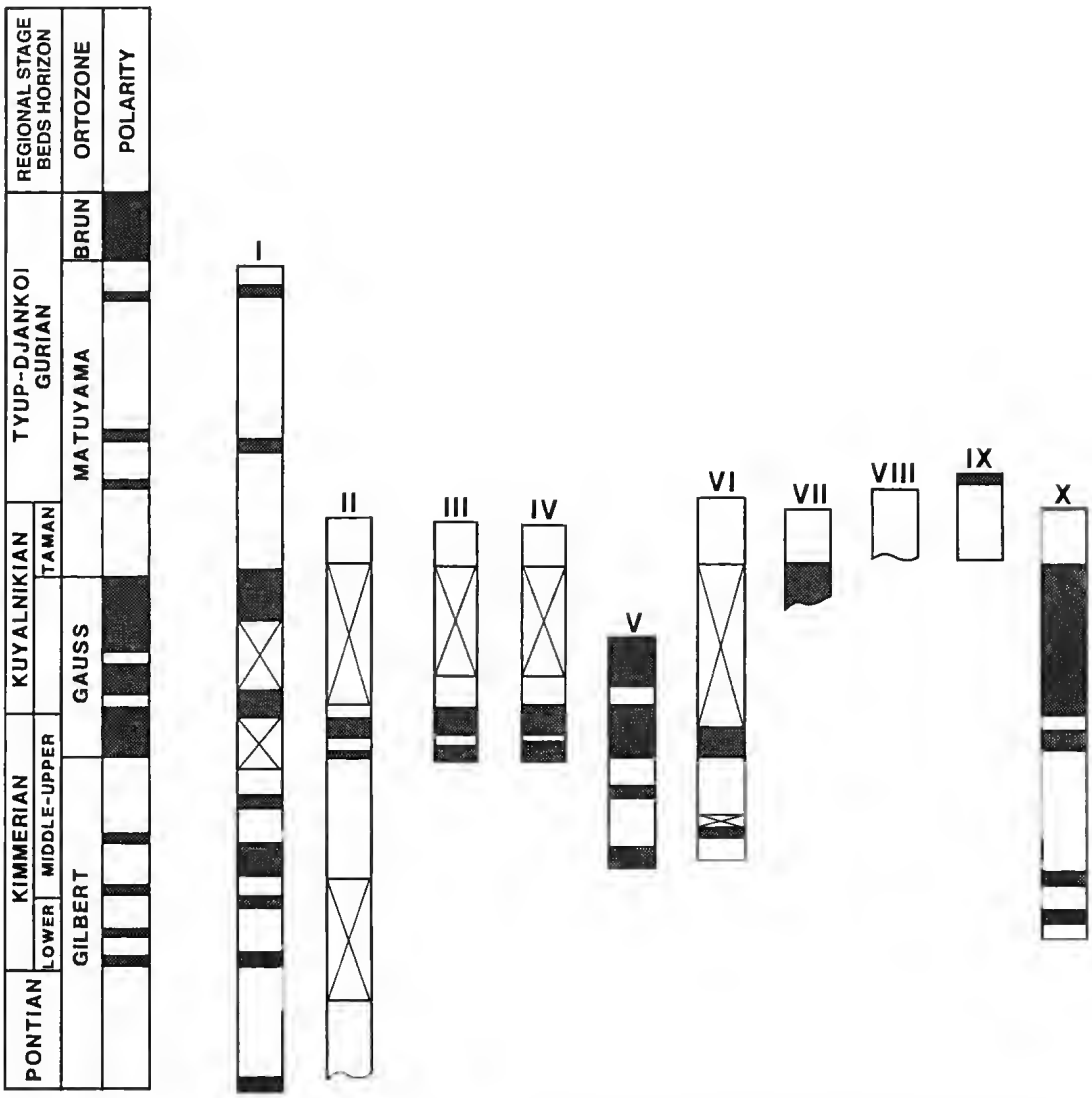


FIG. 9. — Paleomagnetic section and correlation of the Pliocene deposits of north-western Cis-Pontic region. **I**, Chegercha synclinal fold (Semenenko & Pevzner 1979); **II**, Tobechnik; **III**, Arshintsevo (II, III: Molostovsky 1986); **IV**, Arshintsevo; **V**, Lubimovka (Sevastopol); **VI**, Krasny Kut; **VII**, Babach-Tarama; **VIII**, Kryjanovka; **IX**, Liventsovka (IV-IX: Treyak & Volok 1976); **X**, Taman Peninsula (Zubakov & Kochegura 1976).

from the Crimea and Taman are shown in figure 9. Their comparison demonstrates a similar sequence in magnetic polarity changes along the stratigraphic scale.

The Pontian stage is everywhere characterized by reverse magnetization. The main part of the Kimmerian section is composed of the rocks with dominating reverse polarity Jn; four normal polarity subzones are distinguished there (Semenenko & Pevzner 1979). Higher in the section, a normal magnetization interval is recorded, embracing the most of the upper Kimmerian and the lower Kuyalnikian. In the upper Kimmerian part of the section, two reverse polarity subzones are documented in the Lake Tobechik section. The upper Kuyalnikian (Taman layers) is everywhere composed of reverse polarity Jn rocks.

The similar paleomagnetic column structure is characteristic of the continental analogues of the Kuyalnikian regional stage. The lower horizon with the Kuyalnikian microtheriofauna there is characterized by normal magnetization, the upper one, characterized by the Odessa small mammal complex, is reversely magnetized (Tretyak & Volok 1976).

The reverse-polarity interval passes on from the Tamanian layers to the Tyup-Djankoian and Gurian beds and terminates in the lowermost of the covering loam sequence, the major portion of which forms a part of Brunhes magnetozone.

The order revealed in the Pliocene magnetozone stratigraphy (R, N, R), combined with reasonable reliable paleontologic control, allows correlation of the magnetozones with Gilbert, Gauss and Matuyama zones. Their stratigraphic equivalents are:

1. For Matuyama Zone the upper Kuyalnikian, Tyup-Djankoian and Gurian beds.

2. For Gauss Zone the upper horizon of the Kimmerian and the lower Kuyalnikian; r-subzones of the Panikapei horizon probably correlate with the Kaena and Mammoth episodes.

3. Gilbert Zone may involve the bulk of the Kimmerian and the Pontian stage as it is seen in the north-western Cis-Pontic region. N-subzones of the Kimmerian part of the section may be as a group identified with Gilbert-zone episodes.

The northern Cis-Caspian and Low Volga region

The Pliocene deposits from this vast region are poorly studied paleomagnetically, and at present the data on just eight reference wells are available. The principal Upper Pliocene units from the Caspian region have been recognized there according to ostracode and mollusk faunas. The sections were paleomagnetically studied by Eryomin under the guidance of Molostovsky; mollusks were defined by Fedkovich and ostracodes by Karmishina. The principal stratigraphic and paleomagnetic data on the sequence are given below (Kolesnikov 1940; Nevesskaya *et al.* 1986; Muratov & Nevesskaya 1986).

The Actchagylian regional stage

Is subdivided into three substages according to the existing stratigraphic scheme, but the lower Actchagylian deposits in the Volga region are sporadic. In the sections studied, they have been registered only in well N3, where a 17 m thick clay member containing *Dreissena polymorpha* Pallas, *Pisidium amnicum* Muller, *Planorbis planorbis* Linne, was assigned to the lower substage.

The middle substage, built of clays and aleurolites is common; it overlies various formation unconformably right down to the Upper Cretaceous and is characterized by rich and diverse mollusk complex: *Cerastoderma vodgti* (Andrussow), *C. konschini* (Andrussow), *C. pseudoedule* (Andrussow), *Avicardium nikitini* (Andrussow), *Avimactra venjukovi* (Andrussow), *Av. subcaspia* (Andrussow) and by ostracodes: *Loxoconcha varia* Suzina, *Candona convexa* Livental, *C. combio* Livental, *Leptocythere gubkini* (Livental), etc. The middle Actchagylian is 14-125 m thick.

The upper Actchagylian substage conformably overlies the middle one and is represented by 20-70 m thick interbedded aleurites and sands. Small Dreissena, *Avimactra subcaspia* (Andrussow), *Cerastoderma dombra* (Andrussow) are known as well as ostracodes: *Paracyprideis naphatatscholana* (Livental), *Cyprideistorosa* (Jones), etc.

The Apsheronian regional stage

Division of this into three parts is commonly accepted. The lower substage is restricted to the

south of the territory (wells N1, 123), where it conformably overlies the Actchagylian deposits and is separated from the later ones by a monotonous, poorly fossiliferous series containing mainly representatives of *Dreissena* genus: *D. distincta* Andrussow, *D. polymorpha* (Pallas), *D. eichwaldi* Andrussow, etc.

The lower Apsheronian are lithologically represented by grey aleuritic clays 14-18 m thick in the wells investigated.

The middle Apsheronian over most of the region transgressively overlies the eroded surface of the Actchagylian structures. It is composed of grey calcareous-clays, aleurites and sands containing rich mollusk assemblages: *Parapscheronia raricostata* (Sjogeren), *P. eurodesma* (Andrussow), *Monodacna minor* Andrussow, etc; its thickness ranges from 60 to 330 m.

The upper Apsheronian is lithologically similar to the middle Apsheronian and there is a gradual transition between them. This interval of the section is characterized by sharp depletion of malacofauna dominated by small *Dreissena*. Rare remains of *Monodacna*, smooth *Apscheronia*, *Pseudocatillus* occur. The upper Apsheronian deposits are 20-40 m thick.

Comparison

In many sections, the rhythmic character of sedimentation is well pronounced. Each rhythm includes a sandy (regressive) and a clayey (transgressive) member, with a sum thickness of 30-50 m. Among the authigenic minerals, siderite and iron hydroxides are characteristic of regressive facies, while magnetic iron sulfides and pyrite are characteristic of transgressive ones. Fine clastic (0.05-0.001 mm) magnetite in various amounts is present in all the facies.

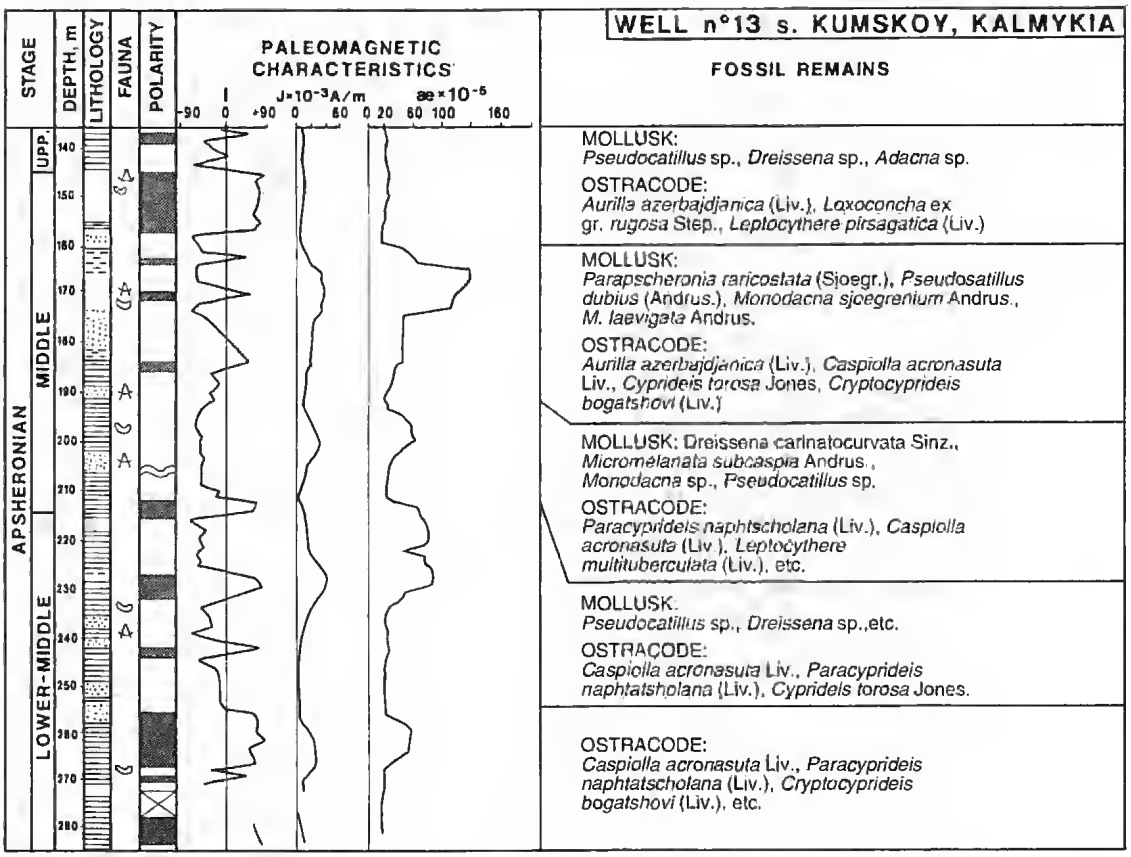


FIG. 10. — Paleomagnetic section of the Pliocene deposits of the wells (settlement Kumskoy, Kalmykia).

Transgressive and regressive sedimentation stages are recorded by sharp variations of scalar magnetic characteristics. In transgressive clay facies, the values of Jn = 20-150 × 10^{-3} A/m, æ = 80-500 × 10^{-5} SI units. In regressive sand facies Jn = 0.5 × 10^{-3} A/m, æ = 10-30 × 10^{-5} SI units. The magnetic-mineralogic analyses have revealed authigenic iron sulfides of the pyrrhotine-greigite (melnikovite) group to be the main NRM-carriers in the transgressive parts of the rhythms. In

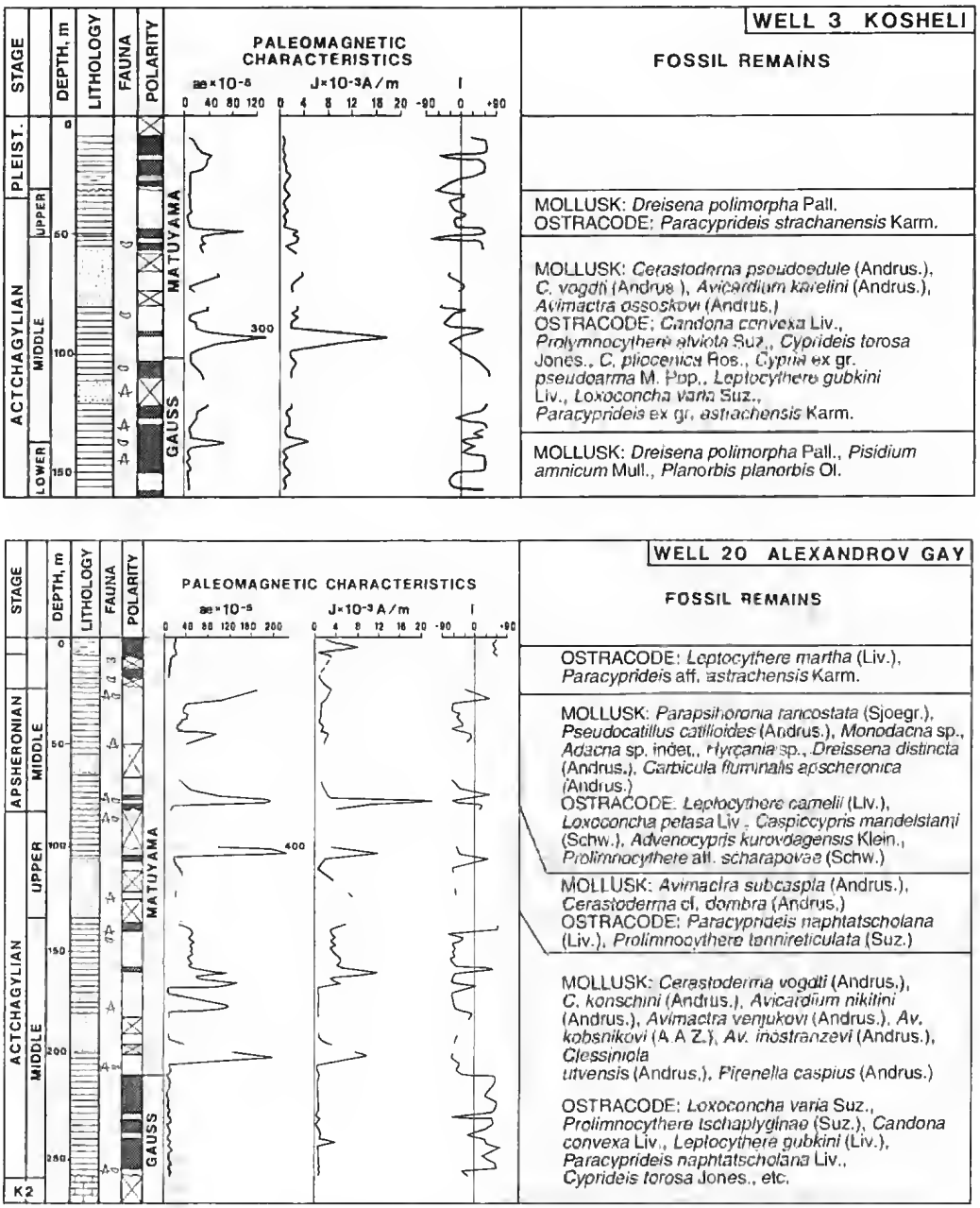


Fig. 11. — Paleomagnetic sections of the Pliocene deposits in Saratov-Volga region.

regressive sand facies, magnetization is determined by clastic magnetite. Thus, in most sections of marine Pliocene from the North Cis-Caspian, alternating intervals are observed: these of dominant detrital or chemical remanent magnetizations.

One should be especially cautious while interpreting the data on the rocks with their magnetization caused by authigenic sulfides. The latter ones are quickly oxidized under atmospheric conditions, thus, the cores should be analyzed not later than in two to three weeks after extraction from the wells. While analyzing the results, those of the first thermal cleaning step (below 350 °C) and those of the second one (550-580 °C) separately. At the first stage, chemical remanent magnetization is dominant in such rock types; at the second stage, after passing the Curie point for sulfides, magnetite remains the only NRM carrier.

To construct the paleomagnetic columns, the only samples used were those with the chemical and detrital Jn components revealing the same type of orientation in space (Fig. 4E-H).

Notwithstanding the differences in lithology, facies and compositions of magnetic phases, there is a stable temporal regularity in the behaviour of natural remanent magnetization in the recent deposits from the North Cis-Caspian and Volga regions.

Within the range from the lowermost part of the Pleistocene to the lower Actchagylian inclusive, two large paleomagnetic intervals are omnipresent: the upper, reverse polarity one, and the lower, normal polarity one. The reverse-polarity zone accounts for the whole of the Apsheronian and the upper half of the Actchagylian stages and the normal-polarity zone corresponds to the lowermost middle and lower Actchagylian (Figs 10, 11).

Matuyama and Gauss zones may be considered as their analogues in magnetochronologic scale. Within the Matuyama Zone, some narrow normal-sign zones have been revealed, which may be correlated according to their stratigraphic position with Reunion (middle-upper Actchagylian boundary), Olduwai (the base of the Apsheronian) and Jaramillo (the uppermost middle Apsheronian) events.

Western Turkmenia

Paleomagnetic studies of the Pliocene deposits in the Trans-Caspian region were carried out separately by Khramov (1963) and Trubikhin (1977). Khramov (1963) has investigated the Middle Pliocene red-bed (Cheleken) Formation, Actchagylian and Apsheronian regional stages. Trubikhin has examined the Upper Pliocene sequence comprising the Apsheronian and Actchagylian stages.

The Cheleken Formation

The Cheleken Formation is composed of red and grey clays, aleurolites, sandstones and contains rare remains of mollusks *Turrucaspia* sp., *Hyrobia* sp, and brackish-water ostracodes of the genera *Hiocypris*, *Limnocythere*, *Cyprinotus*.

Maximum thicknesses occur in the Cheleken Peninsula (2600 m) and they reduce to 200-300 m to the east (Muratov & Nevesskaya 1986).

The Actchagylian and Aspheronian regional stages

It is commonly accepted that, within the sections studied by Khramov, the Actchagylian beds conformably overlie the Cheleken Formation delete. They are generally composed of rocks with reverse remanent magnetization; the overlying lower and middle Apsheronian beds are also reversely magnetized.

Trubikhin has performed complex studies (paleomagnetic and lithologic-mineralogic) of twenty sections of the Actchagylian and Apsheronian stages in the western Turkmenian Depression and Kopet-Dag foothills (Trubikhin 1977). Thick (200-700 m) Upper Pliocene sequences of marine and continental origin are developed in these regions. In the sections studied, grey clays and sand-interlaid aleurolites dominate; they were divided in detail according to the mollusk faunas. Nevesskaya has revealed the following from Trubikhin's collections:

1. In the lower Actchagylian, *Mactra subcaspia* Andrussow, *M. carabugasica* Andrussow, *M. ovala* Tschelzov and *Cardium dombra* Andrussow.

2. In the middle Actchagylian, multiple *Mactra subcaspia* Andrussow, *M. instranzevi* Andrussow, *M. aviculoides* Andrussow, *Cardium dombra*

Andrussow, *C. cucurtennse* Andrussow, *C. konschini* Andrussow, etc.

3. The upper Aktchagylian substage is characterized by brackish-water *Dreissena*, *Clessionola*, *Micromelania* and *Teodoxus* along with depleted *Cardium* and *Mactra* assemblages.

Representatives of *Dreissena*, *Micromelania*, *Teodoxus*, *Didacnomija*, *Pseudocatilus* and other genera are characteristic of the Lower Apsheronian. The middle Apsheronian is characterized by diverse *Cardium Apscheronia*, *Paraapscheronia*, *Monodacna* and other genera. *Hypanis*, *Hircania*, *Micromelania*, *Monodacna*, *Dreissena* occur in the upper Apsheronian.

Comparison

Principal magnetostratigraphic sections for the Upper Pliocene in western Turkmenia are presented in figure 12. They clearly demonstrate the bizonal structure of the paleomagnetic column,

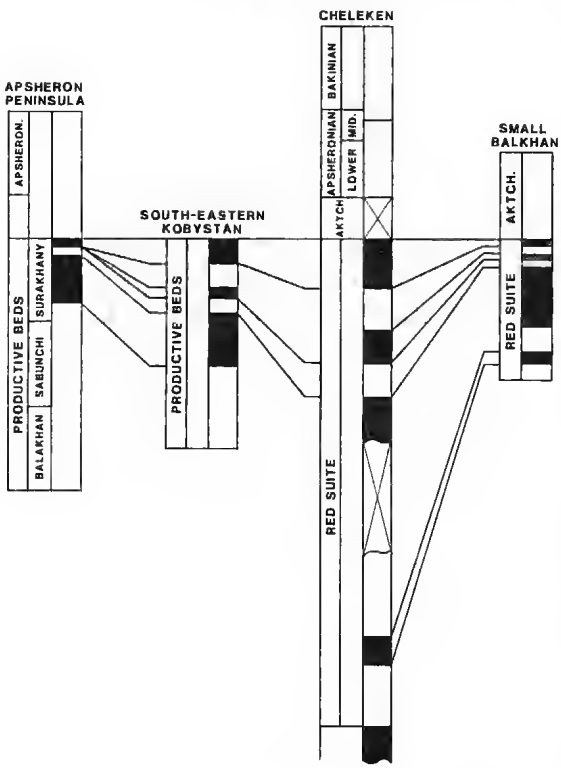


Fig. 12. — Paleomagnetic correlation of sections of the Pliocene and Pleistocene deposits of eastern Azerbaijan and western Turkmenia (Khramov 1963).

with the lower, normally-magnetized zone embracing the lower and the lowermost middle Aktchagylian. The stratigraphic range of the upper, reversely polarized zone is wider and includes the upper parr of the Aktchagylian plus the whole of the Apsheronian. Trubikhin (1977) interprets the regional N and R zones as being analoguous to Gauss and Matuyama zones in standart magnetostratigraphic scale.

Khramov's paleomagnetic column extends Trubikhin's scheme within the Middle Pliocene. If peculiarities of paleomagnetic section structure are considered, it seems possible that the Gauss Zone is not confined to the Aktchagylian, but includes the normally magnetized uppermost of the Cheleken series sequence. The predominantly reversely magnetized middle and lower parts of the Cheleken may be correlated with Gilbert Zone.

The paleomagnetic data available evidently do not conform to the traditional concept of the Aktchagylian discordantly overlying the red-bed and the Torongly suites. This conclusion may be explained by the absence of the lower, normally magnetized Aktchagylian beds (Aktchagylian-Gauss) in the highs of the Cheleken Peninsula, where the red-bed suite is overlain by the Aktchagylian beds with reversely-polarized natural remanent magnetization (Aktchagylian-Matuyama). Hence, the correctness of the conclusion on the lower Aktchagylian horizons is thinning on the ancient structure during the period before the second Aktchagylian transgression.

In the more easterly regions of the Turkmenian Depression, the normally magnetized, lower part of the Aktchagylian is available, but the Cheleken part of the Gilbert Zone falls out of the section and the marine Aktchagylian with latent discordance overlies the reversely magnetized Torongly Formation, assigned to the Gauss Zone by Trubikhin (1977).

Azerbaijan

Eastern Azerbaijan is among the most paleomagnetically-studied regions. Following Khramov's pioneering works (1963), the majority of the most representative sections have been studied

including the Lower Pleistocene, Apsheronian, Actchagylian beds and the Balakhan (productive) sequence of the Middle Pliocene.

The productive sequence

It is formed by the sediment accumulations of a brackish-water basin; they are represented by alternating aleurolites, clays, sands and sandstones with the total thickness up to 2500 m. The section is subdivided into several parts.

The upper part of the sequence, right to the base of the Balakhan suite, is characterized by a relict ostracode fauna of *Bakunella*, *Pontoniella* and *Caspiola*, genera common in the Pontian stage. The Balakhan, Sabunchi and Surakhany suites, constituting the upper part of the productive sequence, contain the Actchagylian ostracodes: *Limnocythere*, *Leptocythere*, etc. (Nevesskaya *et al.* 1986; Muratov & Nevesskaya 1986).

The Actchagylian stage

It is represented by grey aleurolites and clays with sand and rare limestone and conglomerate interlayers. The thickness of the Actchagylian varies between 50-70 and 600-800 m and it is subdivided into three parts according to malacofaunal composition. The criteria used for this division are the same as for the Trans-Caspian region: a depleted assemblage in the lower Actchagylian (*Cerastoderma*, *Clessiniola*, *Pirenella*, *Mactra*), a rich assemblage of the middle Actchagylian *Cardium*, a depleted assemblage of *Mactra* and *Cardium* in the upper Actchagylian (Ali-Zade 1954; Muratov & Nevesskaya 1986).

The Actchagylian beds transgressively and unconformably overlie ancient deposits of the Middle Jurassic. The Balkhan series is the only exception and is believed to be connected with the Actchagylian through gradual intertransitions.

The Apsheronian regional stage

It is lithologically similar to the Actchagylian and differs in paleontologic nature. The Apsheronian deposit thicknesses do not exceed 250-300 m on the highs and are as high as 1500-2000 m in the depressions. The Apsheronian is divided into three substages according to the composition of mollusk fauna (Muratov & Nevesskaya 1986).

The lower Apsheronian is characterized by *Monodacna*, *Dreissena*, *Hyrcania*, *Corbicula* and other genera. The middle substage is distinguished by the development of *Monodacna* and *Didacnaides* genera, and for origination of new species of *Hircania* and *Apscheronia* genera.

The upper Apsheronian is characterised by the disappearance of the ribbed apsheronids (*Apscheronia*) widely common in the middle substage (Nevesskaya *et al.* 1986; Muratov & Nevesskaya 1986).

Comparison

In Khramov's magnetostratigraphic scheme (1963), based on the sections from the Apsheron Peninsula and Kobystan, magnetic zones of the Apsheronian and Actchagylian are recognized, as well as those in the upper part of the productive sequence within the Surakhan, Sabunchi and Balakhan Formations (Fig 12).

According to Khramov's and Ismail-Zade's data, the Actchagylian and Apsheronian stages in eastern Azerbaijan are united by a common zone of reverse polarity. The underlying beds of the Surakhan are marked with dominant normal magnetization both in the Apsheron Peninsula and Kobystan. A large interval of stable reverse polarity is registered downwards through the section; it includes the Sabunchi and Balakhan suites (Ismail-Zade *et al.* 1967; Khramov 1963).

A relatively detailed survey of the Upper Pliocene part of the section was presented by Ali-Zade *et al.* (1973) and Asadulayev & Pevzner (1973), who has confirmed the bizonal structure of the Actchagylian paleomagnetic section. As in western Turkmenia, the lower half of the Actchagylian stage is composed of normal-polarity rocks, whereas the upper horizons of the Actchagylian and the whole of the Apsheronian are reversely magnetized.

Two normal subzones are recorded within the Apsheronian part of the section. One of them is associated with the Actchagylian-Apsheronian boundary, the other one almost coincides with the middle/upper Apsheronian contact.

Four magnetozones are documented within the composite paleomagnetic section through the Plio-Pleistocene in Azerbaijan. The top normally

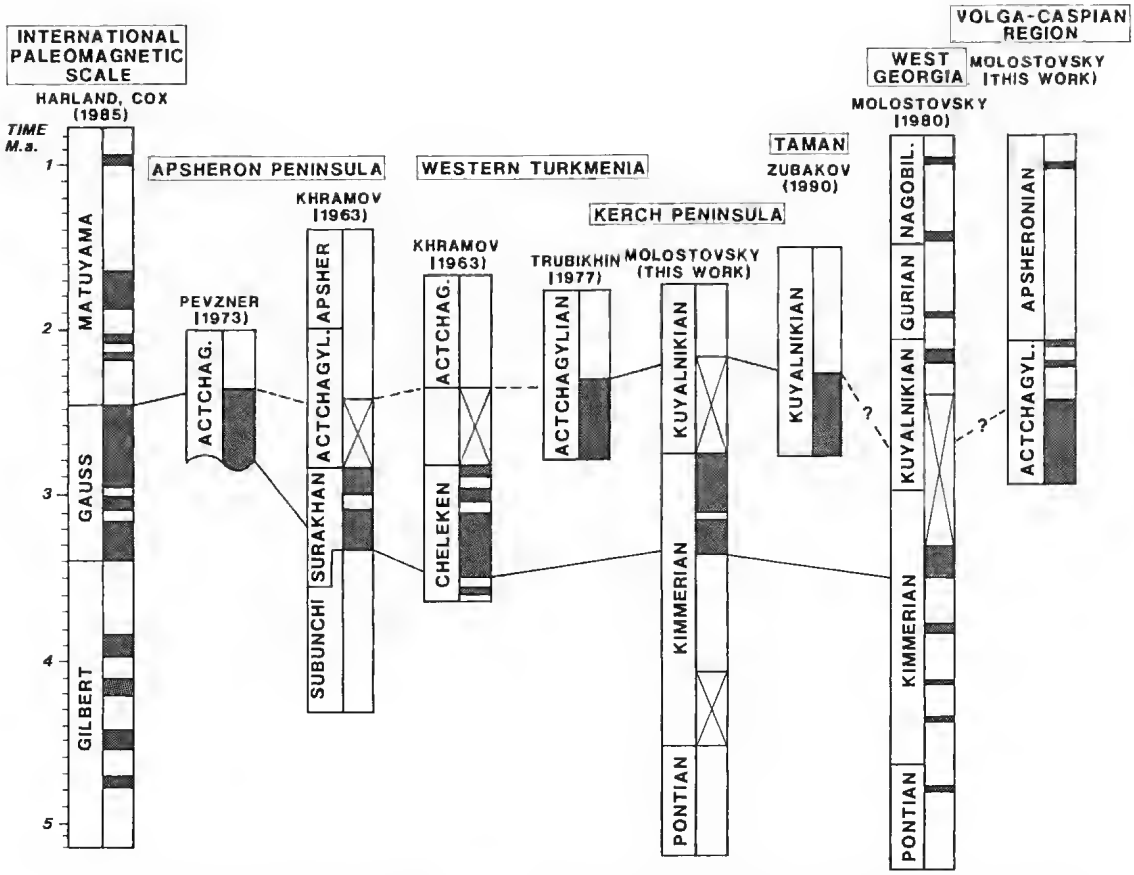


FIG. 13. — Paleomagnetic correlation of the Pliocene and Pleistocene deposits of Black Sea and Volga-Caspian regions.

magnetized zone, equivalent to the Pleistocene, is clearly identified with the Brunhes Zone. The underlying R-zone, which includes the Apsheronian and the upper half of the Actchagylian, is referred to Matuyama Zone by analogy with adjacent regions.

Based on the regional scale pattern, the Gauss Zone should unite the lower half of the Actchagylian and the Surakhan suite.

Such a combination of marine and brackish-water facies within the Gauss Zone is similar to that observed between the Actchagylian and the Chelecen suite in western Turkmenia. Similarly, a stratigraphic discordance is revealed between the Actchagylian and the productive sequence within the section lacking the lower part of the stage and with the Surakhan suite overlain by the reversely magnetized Actchagylian (Fig. 13).

CORRELATION OF THE PLIOCENE DEPOSITS FROM THE BLACK SEA AND CASPIAN REGIONS BY PALEOMAGNETIC DATA

Correlation of the data from western Turkmenia, Azerbaijan, western Georgia, north-western Pontic and northern Cis-Caspian regions, shows practically identical successions in alternation of large normal and reverse-polarity intervals through the whole of the Pliocene section, from the base of the Pontian through the base of the Pleistocene. It should be noted that the same type of magnetic zonation has been revealed within coeval deposits of different origins, irrespective of magnetic phase mineral composition or of the character of natural remanent magnetization.

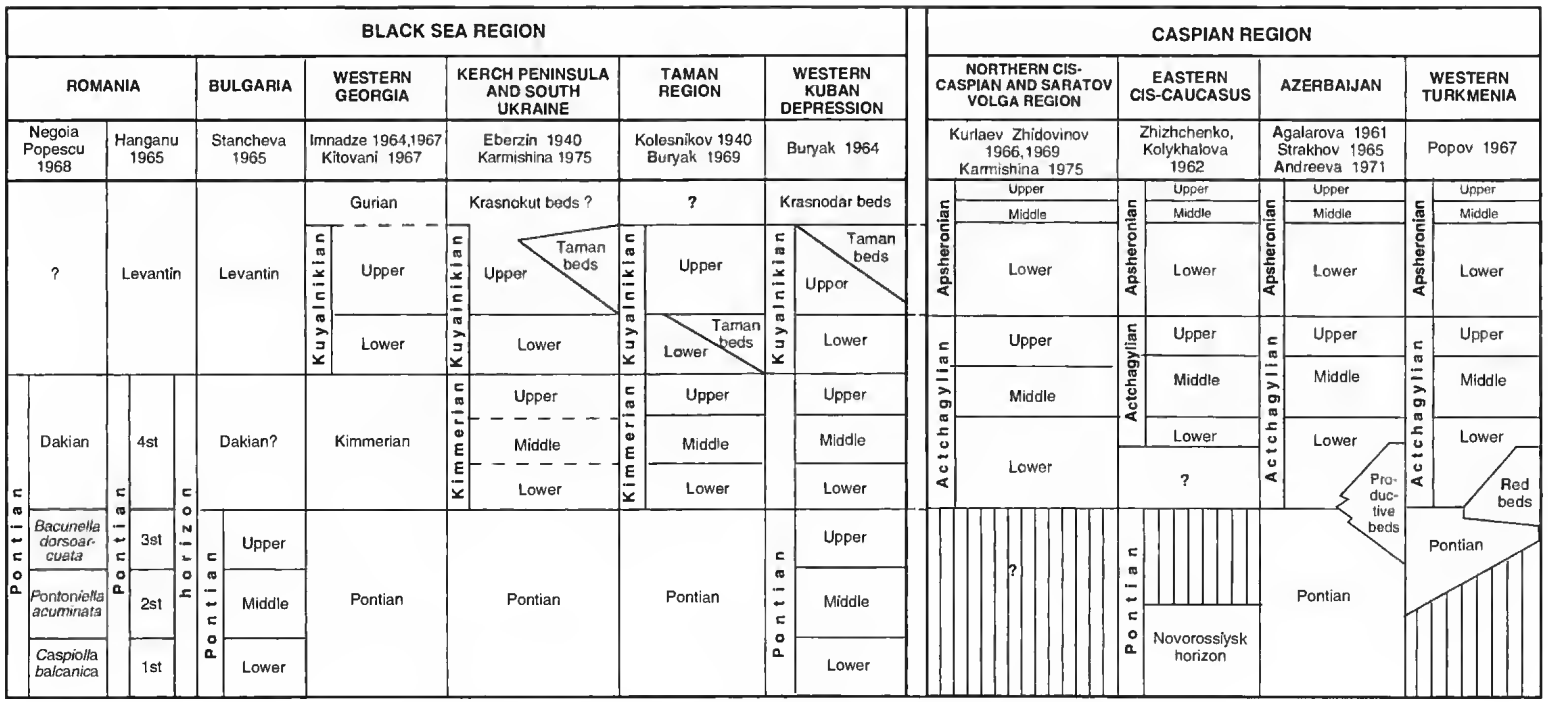


FIG. 14. — Correlative scheme of the Pliocene deposits of Caspian and Black Sea regions (Karmishina 1975).

The Matuyama-Brunhes inversion should be considered the most reliable reference level for inter-regional correlation. The correlation between local stratigraphic units and the paleomagnetic scale is presented in figure 13.

The summary of the biostratigraphic correlation schemes for the Pliocene of the Pontic-Caspian region is shown in figure 14.

Comparison of the schemes makes it possible to consider the revisions introduced by paleomagnetic data into the traditional concepts of Pliocene stratigraphy:

1. The Kimmerian stage cannot be correlated with the middle-lower Actchagylian due to magnetic polarity differences.

2. Paleomagnetic data eliminate the idea of referring the Taman layers to the lower Kuyalnikian (Buryak 1969) due to different polarity Jn of these stratigraphic units. For the same reason, the lower Kuyalnikian cannot be correlated with the upper Actchagylian.

3. Magnetozone correlation between the Pliocene sections from Azerbaijan and Turkmenia does not confirm the traditional idea of the Actchagylian confirmably overlying the productive and red-bed sequences. The Actchagylian overlies various Middle Pliocene horizons transgressively, with clear stratigraphic unconformity.

The proposed paleomagnetic modifications of biostratigraphic schemes do not usually encounter significant objections, the only exception being the Pontian stage and its position within the magnetostratigraphic scale has been debatable for two decades.

There are three published points of view on the problem of the position of the Pontian. Two of them prefer the idea of a "short" Pontian (0.6-0.8 Ma), and correlate the Pontian stage with the lowermost part of Gilbert Zone (Trubikhin 1977; Molostovsky *et al.* 1982) or with zone 6 (Semenenko & Pevzner 1979) of the general paleomagnetic scale. After numerous changes of opinion, Zubakov has assumed of a "long" (about 2 Ma) polyzonal Pontian within the lowermost Gilbert Zone plus the whole of zones 5 and 6 (Zubakov 1990).

The idea of "a long Pontian" seems somewhat speculative, because within the sections from the Crimea, Taman, Georgia and Roumania, the Pontian srage or its analogues correspond to the monopolar R-zone, which is more in accord with the idea of a "short" Pontian.

The idea of correlating the Pontian with the sixth epoch of the paleomagnetic scale originated after NN11 zone nannofossils were found within the lower (Azov) horizon of the Kimmerian and those of the NN12 zone in the Middle Kimmerian.

Based on the nature of nannoplankton and magnetozone distributions within ocean sediments and the stratotype section of the Neogene in Italy, Semenenko & Pevzner (1979) have compared the lower Kimmerian with zone 5 and the upper Messinian, and the Pontian with zone 6 and the lowermost part of the Messinian. The Miocene/Pliocene boundary in the eastern Para-Tethys was, accordingly, removed from the base of the Pontian to the bottom of the middle Kimmerian.

These ideas were questioned (Trubikhin 1986) on the basis of paleomagnetic data for the reference sections of the Mio-Pliocene from Roumania and this present author's data from western Georgia, with the magnetic zonation indicating the correspondence of the Pontian and the lower Kimmerian to the Gilbert Zone and hence to the lowermost Pliocene.

Both models are subject to correction after additional paleontologic and paleomagnetic studies have been carried out.

The study of cores from the equatorial Pacific has shown *Discoaster quinqueramus* to disappear at various stratigraphic levels. In the well PC-12-66, the boundary between zones NN11 and NN12 occurs within the upper third of the foraminifer zone N17, which corresponds to the middle of the paleomagnetic scale fifth epoch. In wells 77 and 158 this change is recorded at a higher stratigraphic level, within zone N18, which is usually correlated with the Gilbert Zone (Dunn & Moore 1981). Thus, the definition of the index-species for the NN11 zone in the Pontic Azov horizon has lost its relerame, because it cannot serve as a correlation index for the Lower Kimmerian and the fifth epoch of the paleomagnetic scale.

The position of Gilbert Zone within the strati-

graphic scale for the Mediterranean has altered in recent years. It follows from Cita (1983) that the conclusions of Ryan *et al.* (1974) on the correlation of the Messinian to magnetozones 5 and 6 were only tentative, because the Messinian stage stratotype has not been studied paleomagnetically due to weak magnetization of the rocks.

Research in eastern Crete has shown that the upper Messinian (evaporites plus "*lago mare*" formations) corresponds to the lowermost part of the Gilbert Zone and the middle and the lower parts of the stage to magnetozones 5 and 6 (Langereis *et al.* 1977).

From the evidence discussed above, it seems most reasonable to refer the Pontian to the lowermost part of the Gilbert Zone and correlate it with the upper Messinian and, partially, with the lower Zanclian. In this case the Miocene-Pliocene boundary, as it is accepted in the Mediterranean, should occur within the Pontian stage.

Paleomagnetic correlation of the Pontian with the Mediterranean units reduces the level of uncertainty arising from biostratigraphic scheme comparisons. Nevesskaya *et al.* (1986) believe that the Pontian may correspond to the Messinian in the Mediterranean, in full or in part, or the lowermost part of the Zanclian, or the uppermost Messinian and lowermost Zanclian.

Magnetostratigraphic correlation of the Pliocene beds from the eastern Para-Tethys and the Mediterranean region is shown in figure 15.

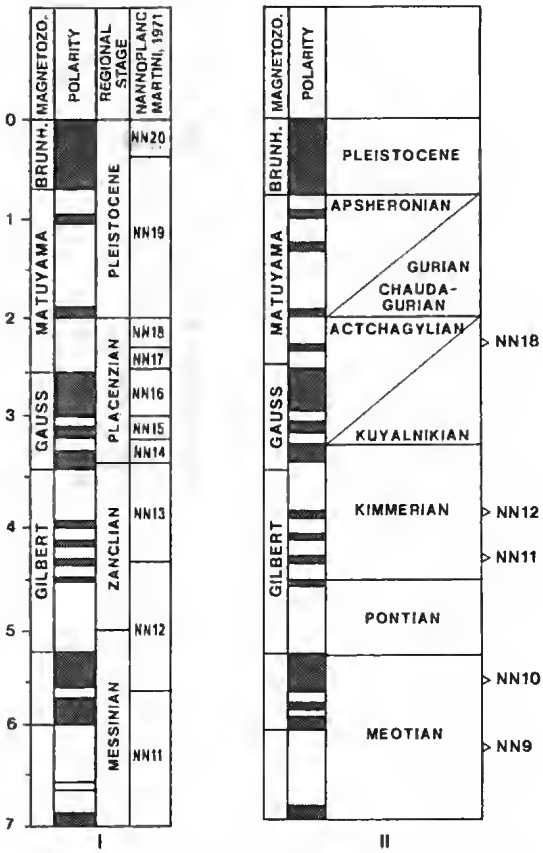


FIG. 15. — Paleomagnetic correlation of sections of the Neogene of Mediterranean (I) and eastern Para-Tethys (II).

PALEOMAGNETIC CALIBRATION OF OSTRACODE AND MOLLUSK FAUNAS FROM THE PONTO-CASPIAN REGIONS

Unification of regional paleomagnetic schemes on the basis of A. Cox scale has provided the framework for a comparative analysis of ostracode and mollusk faunas development stages within the Pontic and Caspian regions. According to Karmishina (1975), three stages may be recognized in the development of the Pliocene basins and their ostracode biota: the Pontian, Actchagylian and Apsheronian for the Caspian; the Pontian, Kimmerian early Kuyalnikian and late Kuyalnikian Gurian for the Euxinic. The Pontian stage is accepted as common for both regions, and the Actchagylian is generally correlated with the Kimmerian early Kuyalnikian Gurian.

Projection of the biostratigraphic scheme on to the paleomagnetic scale reveals the chronologic asynchroneity of a number of evolutionary boundaries (Fig. 16).

Within the Euxinic Basin, the Pontian stage came to an end in the middle of the Gilbert epoch, probably after the Tver episode. The Actchagylian ostracode complex supplants the Pontian one at about the same level within the lowermost part of the Balakhan suite (Karmishina 1975; Muratov & Nevesskaya 1986).

The Actchagylian stage in the Caspian corresponds to the whole of the Gauss epoch and to

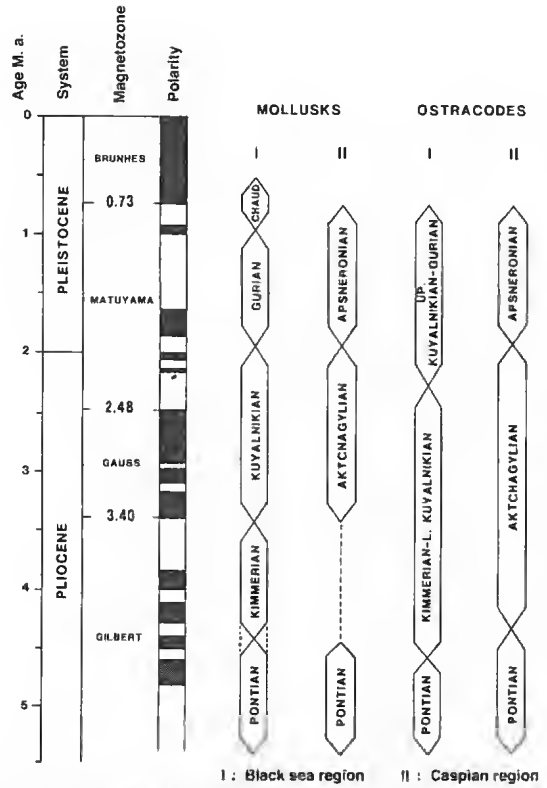


FIG. 16. — Principal studies of development of the Pliocene ostracodes and mollusks of eastern Para-Tethys correlation with paleomagnetic scale (ostracodes: Karmishyna 1975; mollusks: Nevesskaya *et al.* 1986).

the early Matuyama up to Olduwai episode; it covers the time interval of 3.4-1.9 Ma Its presumed analogue in the Pontic region, the Kimmerian early Kuyalnikian stage, occupies a different magnetochronologic interval: the major part of the Gilbert epoch and the whole of the Gauss epoch (4.57-2.47 Ma).

The Apshetonian and the late Kuyalnikian Gurian stages have different durations: their time ranges constitute 1.89-0.73 and 2.47-0.73 Ma respectively. Comparative analysis of the evolution of the Pontic-Caspian malacofauna demonstrates that the Apsheronian stage is equivalent to the Gurian and Chaudian stades collectively in duration, and the Kuyalnikian stage is shorter than the Kimmerian.

In principle, similar relationships based on the magnetic polarity scale may be determined between the Pliocene faunas from eastern and western Para-Tethys as well as between them and the fauna of the Mediterranean region.

CONCLUSION

In the Pliocene sections from the Black Sea and Caspian regions, three major zones of the general magnetochronologic scale are recognized and traced consistently; they are complicated by a number of subordinate subzones. The Upper Pliocene R-zone is identified with the Matuyama Zone (0.73-2.47 Ma) and comprises the most of the Upper Pliocene + Eopleistocene. The middle, Gauss N Zone (2.47-3.4 Ma), comprises the Middle and the lowermost part of the Upper Pliocene. The lower, Gilbert Zone (3.4-5.3 Ma), corresponds to the most of the Kimmerian part of the Middle and Lower Pliocene.

Unification of local stratigraphic schemes, correlations among the regional geologic events and comparisons of marine sections from the eastern Para-Tethys and the Mediterranean region, these are the obvious positive results obtained from many years of paleomagnetic research.

The most urgent task for the nearest future is to perform correlations among the marine and continental Plio-Pleistocene Formations from the northern Peri-Tethys on the basis of paleomagnetic zonalities. There are most real prerequisites available for broad correlations of such type.

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